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Spatial distribution and habitat association of amphibians in the bighorn crags of the Frank Church River of No Return Wilderness

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SPATIAL DISTRIBUTION AND HABITAT ASSOCIATIONS OF AMPHIBIANS IN THE BIGHORN CRAGS OF THE FRANK CHURCH RIVER OF NO RETURN WILDERNESS

1994 FINAL REPORT

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SUMMARY

The objective of this project was to develop baseline information on amphibian species distributions and habitat associations in the lakes of the Bighorn Crags of the Frank Church River of No Return Wilderness (FCRNRW). Very little herpetological information exists for the FCRNRW and, consequently, we believe this report is the first documentation of the distribution and occurrence of amphibian species in the Bighorn Crags. In addition, this report examines the habitat associations of Spotted Frogs (*Rana pretiosa*) and Long-toed Salamanders (*Ambystoma macrodactylum*) in relation to physical, chemical, and biological lake characteristics.

In late July and early August 1994, two person field teams surveyed 28 lakes in the high mountain lakes complex of the Bighorn Crags. The amphibian species and number of individuals observed were recorded at each lake using visual encounter and dipnet survey methodology. Fish presence/absence was determined by hook-and-line angling and visual surveys. To document which environmental variables are associated with amphibian occurrence, we measured elevation, lake size, pH, emergent vegetation, aquatic substrate type, and isolated wetlands in fish and fishless lakes. The spatial relationships between amphibian and fish distributions were mapped using GIS (PC ArcInfo and ArcView) software.

Based on known amphibian ranges in the state of Idaho, seven amphibian species may occur in the Bighorn Crags area. We found three species of amphibians during field surveys in 1994 including Spotted Frogs, Long-toed Salamanders, and Tailed Frogs (*Ascaphus truei*). Fish were found at 24 of the 28 lakes. We found that most environmental lake characteristics such as elevation, substrate, pH, emergent vegetation, and lake size did not significantly explain the observed distributions of Spotted Frogs and Long-toed Salamanders. Spotted Frog adults were found in lakes with fish, however limited amphibian breeding was observed in these lakes and numbers of individuals were low compared to fishless lakes. Spotted Frog tadpoles were found in only 3 lakes with fish and Long-toed Salamander larvae were not found in any lakes with fish. Both frogs and salamanders used fishless lakes and isolated wetlands adjacent to lakes for breeding. The results from this study indicate that amphibian distributions may be affected by certain biotic and abiotic habitat characteristics in high mountain lake environments, especially the presence of fish. However, to adequately assess these relationships, more complete and detailed surveys need to be conducted. We plan to continue monitoring amphibian populations in the Bighorn Crags and further assess the distributions and habitat relationships of amphibian populations by performing detailed surveys of all wetlands in the Bighorn Crags between 1995 and 1997.

INTRODUCTION

For a variety of reasons, the demand for information concerning the ecology of amphibians has recently increased, both regionally and globally. One of the major reasons has been the growing number of amphibian species listed as Threatened, Endangered, Candidate, or Sensitive that land managers are required to consider. Another reason for the increased information demand has been the recent emphasis on ecosystem management combined with a better appreciation of the often important functional roles of amphibians in ecosystem processes (predation, energy flow, nutrient cycling, etc.). Finally, because of a combination of several biological characteristics (e.g., biphasic life cycles, thin, moist skin, external development, and limited vagility), amphibians may be especially sensitive to some environmental factors (e.g., acid rain: Bradford 1991, Bradford et al. 1992, Corn and Vertucci 1992; and increased UV radiation: Blaustein et al. 1994) and thus provide an "early warning system" of environmental changes (Beiswinger 1986).

In the last decade, several studies have documented declines in amphibian populations throughout the western United States (Corn and Fogelman 1984, Bradford 1991, Fellers and Drost 1993, Sherman and Morton 1993). One consequence of recent attention to amphibian populations has been the realization of a general lack of basic information concerning the distribution and status of amphibian populations. This information is essential to understanding amphibian declines and for developing effective conservation strategies for amphibian populations.

The main goal of this study was to collect baseline information on amphibian species distributions and habitat associations in the Bighorn Crags of the Frank Church River of No Return Wilderness Area (FCRNRW). Little herpetological information exists for this large (over 2 million acre) area which contains two Category 2 Candidate Species, the Spotted Frog and Tailed Frog, and one state Species of Special Concern, the Western Toad (*Bufo boreas*) [Conservation Data Center 1994] (Table 1).

An additional goal of this study was to gather preliminary information about the relationships between trout and amphibians in the Bighorn Crags. Considerable data

exist that implicate fish stocking as an important cause of amphibian population declines in high mountain lake environments (Bradford 1989, Bahls 1990, Dudley and Embury 1995, Liss et al. 1995). The correlation of fish presence and subsequent amphibian absence may be attributable to direct affects from predation (Petranka 1983, Taylor 1983, Semlitsch 1988, Bradford 1989, Sih et al. 1992, Liss et al 1995) and competition (Figiel and Semlitsch 1990) as well as indirect affects from habitat loss and disruption of population structure (Bradford et al. 1993). The data from this study will be very helpful in developing a landscape-level study of the effects of stocking predatory fish in mountain lakes on amphibian populations in Wilderness Areas.

The specific objectives of this study included:

1. Identification of the amphibian species that occur in the Bighorn Crags ecosystem.

2. Determination of amphibian distributions and numbers observed in lakes and adjacent wetlands with reference to two age classes: adults and larvae.

3. Documentation of the habitat associations (physical, chemical, and biological) of each amphibian species.

4. Comparison of amphibian distributions in stocked versus unstocked (fishless) lakes.

To accomplish these objectives, we conducted habitat descriptions and amphibian surveys in 28 lakes throughout the Bighorn Crags ecosystem. The information from these surveys provided information for identifying potential sites for future amphibian research and long-term monitoring. The baseline data generated from this project are being used for a detailed investigation of the interaction of stocked fish and amphibian species from a landscape perspective (Pilliod and Peterson, Idaho State University).

METHODS

Study Area

The Bighorn Crags are a cluster of steep, rugged peaks located in the Salmon River Mountains of central Idaho. Bordered by the Middle Fork of the Salmon River to the west and the main Salmon River to the North, the Bighorn Crags encompass several hundred square kilometers in the southeast portion of the FCRNRW. The area is managed by the North Fork Ranger District of the Salmon National Forest.

The topography of the Bighorn Crags area is steep with elevations ranging from 900 m along the Middle Fork of the Salmon River to over 3000 m on Mount McGuire. The rugged ridge system is comprised of glacial cirques with interspersed alpine lakes and forested basins. The range forms some of the highest mountains in the FCRNRW and includes over 75 glacial lakes.

The majority of the lakes in the Bighorn Crags occur in a 40 square kilometer area with Ship Island and Big Clear Lakes forming the northern boundary and Plateau and Alpine Lakes forming the southern boundary (Figure 1). Twenty-eight lakes were surveyed in this core area with 14 lakes in each of two survey areas:

Northern Survey Area (Figure 2a):

1. Glacier Lake
2. Pothole Lake
3. Big Clear Lake
4. Gooseneck Lake
5. Crater Lake
6. Mirror(w) Lake
7. Gentian Lake
8. Birdbill Lake
9. Shoban Lake
10. Sheepeater Lake
11. Wilson Lake
12. Harbor Lake
13. Heart Lake
14. Welcome Lake

Southern Survey Area (Figure 2b):

1. Skyhigh Lake
2. Turquoise Lake
3. Echo Lake
4. Reflection Lake
5. Twin Cove Lake
6. Fawn Lake
7. Doe Lake
8. Buck Lake
9. Tip Top Lake
10. Unnamed Lake (NW Ramshorn)
11. Ramshorn Lake
12. Paragon Lake
13. Alpine Lake
14. Unnamed Lake (SE Alpine)

Fish are stocked in many of the lakes of the Bighorn Crags by the Idaho Department of Fish and Game. Currently the lakes are stocked every three years from fixed-wing aircraft. Most lakes are stocked with cutthroat trout (*Oncorhynchus clarki*), although historically rainbow trout (*O. gairneri*), grayling (*Thymallus arcticus*), brook trout (*Salvelinus fontinalis*), and golden trout (*O. bonita*) were also commonly planted (Idaho Department of Fish and Game Stocking Records).

Survey Schedule

The southern survey area (Figure 2b) was surveyed by David Duncan (University of Idaho) and Dan Duncan (Enterprise, Oregon) between 30 July and 1 August. The northern survey area (Figure 2a) was surveyed between 14 and 17 August 1994 by David Duncan and Raymond Clark (Idaho State University). Each lake was surveyed once during daylight hours between 0855 and 1755.

Site Descriptions and Environmental Measurements

At each survey site, an environmental description was performed by measuring and observing the abiotic and biotic characteristics of the lake habitats. We chose the lakes to be surveyed based on an attempt to have equal numbers of stocked and unstocked lakes in the study. Survey sites were chosen from information obtained from Idaho Department of Fish and Game's fish stocking records (Peter Landres, Aldo Leopold Wilderness Research Institute, personal communication). Based on field measurements and species observations, "lake types" were determined for each lake surveyed. Lake types were categorized by lake size, depth, fish occurrence, amphibian occurrence, amphibian breeding, and presence of isolated wetlands.

We took colored slides of each lake and a photographic example of each "lake type" is included as Appendix A. All other photographs were archived in the herpetological collection at the Idaho Museum of Natural History in Pocatello, Idaho.

Physical Description: We recorded the physical parameters of each lake during each survey period. Elevations and locations were recorded from 1:24,000 scale U.S.G.S.

topographic maps. We used ArcView 2.1 (ESRI, Inc., Redlands, CA) to calculate both lake size and shoreline perimeter from digitized topographic maps (See Mapping). Air temperatures were recorded using quick-reading mercury thermometers (Miller and Weber, Queens, NY) held 1 meter above the ground and shaded from the sun. We recorded surface water at 1 - 2 centimeters below the lake surface. The dominant substrate type, north shore characteristics, and distance to forest edge were also documented. Finally, each lake was classified using the National Wetlands Inventory system (Cowardin et al. 1979).

Water Chemistry: The pH of each lake was measured using an Oakton "pH tester 2" (Forestry Supply, Jackson, MS) with accuracy to +/- 0.2 pH units. The lake water conductivity of all northern lakes were measured using an Oakton "TDS Tester 3" with automatic temperature compensation with accuracy to +/- 10 μS (Forestry Supply, Jackson, MS).

Biological Description: Biological characteristics of each lake habitat were recorded, including dominant vegetation (aquatic and terrestrial) types and percent cover, and fish presence or absence. Fish presence/absence was determined using visual observations. Incidental hook-and-line sampling was performed in the southern lakes only.

The observations and measurements from each survey were recorded onto Amphibian Survey Data Sheets developed by P. Corn (U.S. Fish and Wildlife Service, Ft. Collins, CO [Appendix B]). The data from each form were then entered into a PC spreadsheet (Appendix C).

Amphibian Surveys

All 28 lakes were surveyed for amphibians using a standardized visual encounter survey (Crump and Scott 1994). This technique involves walking the perimeter of each lake sweeping shallow water with a dipnet and visually counting adults, subadults, larvae, and egg masses for each amphibian species. Isolated wetlands adjacent to lakes were included in the data forms for the associated lake.

Mapping

In the laboratory, we scanned in the appropriate portions of the topographic maps with a Hewlett-Packard ScanJet IIcx scanner. The maps were scanned in as 16-color photo images at 180 dpi with normal sharpening, and saved as TIFF files. The TIFF files were then imported into Corel Draw 4.0 (Corel Corporation, Ottawa, Ontario, Canada). We added the site numbers and abbreviations for the amphibian species observed and then printed the maps with an Epson Color Stylus printer at 360 dpi (Figures 1, 2).

We used a 36" x 48" CalComp 9500 digitizing table (CalComp, Scottsdale, AZ) to digitize UTM coordinates from the USGS 7.5 minute series topographic maps (Hoodoo Meadows and Mount McGuire quadrangles [1962]; NAD 1927 datum). These coordinates should be accurate to within about 25 meters. Appendix C lists the coordinates for the lakes. The digitized map coordinates were brought into PC ArcInfo to build coverages for the study area and mapped using ArcView 2.1 (ESRI, Inc., Redlands, CA).

Statistical Analysis

To explain the distribution patterns of Spotted Frogs and Long-toed Salamanders in the Bighorn Crags, we measured several environmental characteristics that might influence amphibian distribution, including elevation, lake substrate, pH, fish, emergent vegetation, and lake size. The number of lakes each species occurred at ("used") was compared graphically to the total number of lakes surveyed ("available") over the range of several variables measured. To compare the number of lakes where each species was found (present) versus not found ("absent") for each variable measured, we performed multiple, uni-variate, non-parametric Contingency Table Analyses. The statistical significance of each of these relationships (found versus not found for each species, independently) was tested using a Fisher's Exact Test (SPSS 6.1, Chicago, IL) for 6 variables (elevation, substrate, pH, fish, emergent vegetation, and lake size). To reduce the cumulative probability of committing a type I error with multiple non-orthogonal comparisons, we used a Bonferroni correction which reduced our family-wise error by

adjusting our chosen alpha level (α=0.05 before Bonferroni adjustment). We chose the Bonferroni method because of it's simplicity and conservative approach (Keppel 1991, Sokal and Rohlf 1995).

RESULTS AND DISCUSSION

Species Occurrence

We are not aware of any herpetological records for the Bighorn Crags ecosystem, although recent studies in the Big Creek drainage of the FCRNRW (Peterson, unpublished data) have documented populations of four species: Spotted Frogs, Long-toed Salamanders, Western Toads, and Tailed Frogs. We observed both Spotted Frogs and Long-toed Salamanders in the lakes and wetlands of the Bighorn Crags ecosystem. Incidental observations of Tailed Frogs were also recorded, however we did not adequately survey stream habitats to determine abundance of stream amphibian species. Western Toads were not observed in 1994 and only one small population was discovered through intensive surveys in the summer of 1995 (Peter Ritson, Portland, Oregon, personal communication).

There is considerable variation in the distribution of amphibians in Idaho and the Intermountain West. Both Spotted Frogs and Long-toed Salamanders are widespread throughout the northwest with populations ranging from sea level to 3000 m. (Nussbaum et al. 1983). Western Toads are widespread in Idaho although their numbers in southeastern Idaho appear to have declined over the last few decades due to unknown causes (Peterson, unpublished data).

We did not observe any amphibian egg masses although we did not expect to find egg masses so late in the summer. The presence of Spotted Frog tadpoles and Long-toed Salamander larvae indicated the presence of egg masses earlier in the season. Some species of pond and stream breeding amphibians overwinter in the larval stage (Nussbaum et al. 1983), although in the lakes with active breeding, only one size class of larvae from each species was observed. Further research into the life history of the

amphibians in the Bighorn Crags will provide more detailed information about the age of the life stages observed.

We did not observe Tailed Frog larvae in any streams or lakes in the Bighorn Crags. Tailed frog larvae are known to overwinter for several years in other areas of the FCRNRW (Peterson, unpublished data) and thus we expected to find larvae in the streams of the Bighorn Crags. However, low water levels in many of the streams may have limited Tailed Frog breeding habitat and distributions. The apparent absence of Tailed Frog larvae in the streams of the Bighorn Crags may also be the result of our survey efforts which focused on lake more than stream habitats. Therefore, our data on Tailed Frog larvae occurrence may not reflect the actual status of Tailed Frogs in the Bighorn Crags. Consequently, we did not include our observations of Tailed Frogs in any statistical analyses. Future surveys will be conducted to better assess the distribution and abundance of this species (Pilliod and Peterson, Idaho State University).

Spatial Distribution

Spotted Frogs were widely distributed throughout the study area occurring at 18 of 28 (64%) lakes surveyed. Spotted Frog tadpoles were less widely distributed, occurring in lakes or in adjacent wetlands at only 8 of 28 (29%) surveyed lakes (Figs. 2a,b; 7).

Long-toed Salamanders had a very limited distribution, occurring at only 5 of the 28 (18%) lakes surveyed (Figs. 2a,b; 7). Salamander larvae were observed at 5 of 28 lakes whereas adults were found at only 2 of 28 lakes (7%) [Table 2]. Survey methodology tended to focus on the aquatic life stages of amphibians and consequently observations of terrestrial adult salamanders were rare. The overall low abundance of Long-toed Salamanders may have been biased by our selection of lakes which unevenly sampled stocked versus unstocked lakes and large versus small lakes. Liss et al. (1995) found that small, shallow lakes tended to have the highest densities of salamander larvae and thus our under representation of this lake type may have resulted in an underestimation of the occurrence of salamander populations. In addition, salamander larvae are known to be highly susceptible to fish predation due to their foraging behavior and activity patterns (Petranka 1983) and thus the high number of stocked versus unstocked lakes surveyed

may also have underestimated the actual abundance of Long-toed Salamanders in the area.

Spotted Frogs co-occurred at every lake where Long-toed Salamanders occurred, however we found many lakes with Spotted Frogs but without Long-toed Salamanders (Table 2). The distributions of Spotted Frogs and Long-toed Salamanders in the Bighorn Crags cannot be explained by the physical (with the exception of lake size) and chemical characteristics of the habitats surveyed. However, we found a significant relationship between the presence/absence of fish and the occurrence of frog and salamander larvae.

Habitat Associations

Physical Characteristics:

Elevation: Lake elevations in the study area ranged from 2347 m (7700') to 2726 m (8945'). Neither Spotted Frogs nor Long-toed Salamanders appeared to occur at a specific elevation more than any other (Figure 4) and there was no significant difference ($P=0.078$ and $P=0.045$, respectively, $\alpha=0.008$) between the number of lakes where each species was found versus not found over the range of lake elevations [Tables 4a,b]. Because all lake elevations in the Bighorn Crags are within the known range of each species, we did not expect to find a difference between lake elevation and species occurrence. However, the number of lakes sampled ($n=28$) may be too low of a sample size to adequately examine this relationship. In subsequent years we will be able to survey more lakes in the Bighorn Crags and compare these lakes to other lakes in the FCRNRW.

Lake Size: Lakes with a surface area greater than 1.0 ha were classified as large lakes and lakes with a surface area less than 1.0 ha were classified as small. The occurrence of Spotted Frogs was not statistically significant ($P=0.265$, $\alpha=0.008$) with lake size when analyzed using the stated criteria (Table 9a). Similarly, the occurrence of Long-toed Salamanders in small versus large lakes was not significant ($P=0.135$, $\alpha=0.008$) [Table 9b]. We compared the lake size criterion with the presence/absence of fish to determine

if the occurrence of fish is related to the size of lakes surveyed (Table 9c). We found that the presence of fish in larger vs smaller lakes is significant (P=0.011, α=0.05), however this difference may be inadvertently attributable to our study design which favored large (n=24) versus small (n=4) lakes. Further study of this relationship is required.

Substrate: Spotted Frogs appeared to use mud and sand substrate most frequently (Figure 5), however this relationship was not statistically significant when compared with all lake substrates (P=0.186, α=0.008) [Table 5a]. Similarly, there was no difference between substrate type and Long-toed Salamander occurrence (P=0.365, α=0.008) [Table 5b]. We did not compare the presence/absence of breeding with substrate because substrate type was recorded for the main lake body only and most breeding occurred in adjacent wetlands with a different substrate. In future studies, we plan to record this information.

Lake Water Chemistry:

pH: Lake water pH levels of the surveyed lakes ranged from 5.8 to 8.0. The occurrence of Spotted Frogs in lake water with pH greater than 7.5 was significantly less than expected (P=0.002, α=0.008)[Figure 6, Table 6a]. There was no statistical difference between the occurrence of Long-toed Salamanders over the range of lake water pH levels (P.=1.000, α=0.008) [Tables 6b]. However, both amphibian species appeared to occur less frequently in lakes with pH levels between 7.5 and 8.0. This pH range is well within the physiological range of both species. However, most of the lakes in this range were the larger stocked lakes, and therefore, the possible pH effect may be the result of another environmental variable such as presence of fish.

Lake water conductivity in the northern lakes of the Bighorn Crags ranged between 0 and 50 μS (Appendix C). Because these measurements indicated very low levels of total dissolved solids and we did not have conductivity measurements for the southern lakes, we did not include conductivity in our analyses of water chemistry.

Biological Characteristics:

Emergent Vegetation: The presence/absence of emergent vegetation was not significant for the occurrence of either species (P=0.669 and P=0.606, α=0.008) [Table 8a,b]. Spotted Frogs often use emergent vegetation for cover, however rocky alpine lake environments may not offer the ideal habitat for this species. Low abundance of emergent vegetation decreases potential cover for amphibians which may increase predation, especially during early life stages. Although not statistically significant, the lack of emergent vegetation may act as another variable contributing to the problems of fish predation.

Fish Stocking: Stocked trout in the Bighorn Crags appear to affect both Spotted Frogs and Long-toed Salamanders in all the stocked lakes surveyed in this study. The levels of this effect are different for each lake and for different amphibian species in these lakes. Although not statistically significant in terms of distribution (number of lakes with adult Spotted Frogs) [Table 7a], the abundance of adult Spotted Frogs appears to be affected by the presence of stocked trout. In lakes with fish, Spotted Frog adults were either absent or occurred in very low numbers (Table 2, Figure 7). This suggests that although adult frogs are able to coexist with fish in high mountain lakes, mortality rates and/or emigration may be very high.

The low abundance of frogs in stocked lakes may also be attributable to lack of breeding habitat. We rarely observed frog tadpoles and never observed salamander larvae in any lakes with fish and consequently the relationship between presence/absence of fish and amphibian breeding was significant (P<0.001 each species, α=0.008) [Tables 7b,c]. Fish predation on amphibian larvae is well documented (Voris and Bacon 1966, Petranka 1983, Hayes and Jennings 1986, Kats et al. 1988, Semlitsch 1988), however it is unclear whether the observed absence of breeding in stocked lakes is due to the fish or to some other environmental characteristic. Because we did not specifically measure the breeding site characteristics, we are unable to address this question. However, other observations suggest a negative correlation between the presence of fish and amphibian reproduction.

The only stocked lakes in the Bighorn Crags to have breeding populations of amphibians were those lakes with isolated habitat adjacent to the stocked lake or complex shorelines with vegetated shallows (Table 3, Figure 3). In each of these cases, amphibian larvae were found in isolated wetlands (ponds, isolated temporary pools, springs) adjacent to the stocked lakes whenever available. The limitation of breeding in these isolated wetlands indicates a negative effect of fish presence (Semlitsch 1988, Sih et al. 1992). For example, the use of isolated wetlands indicates that fish predation may be strong enough to eliminate breeding activity in stocked lakes. Also, if amphibians are restricted to these isolated wetlands for breeding, there may be an increase in larval mortality due to marginal breeding conditions in terms of temperature, pH, hibernation, etc. Both these situations imply a potential decrease in population viability for amphibians in stocked environments.

Several studies on the distribution and abundance of ambystomatid larvae in lake environments have found that the predation on eggs and larvae by fish has often excluded successful reproduction of salamanders in lakes with fish (Petranka 1983, Taylor 1983, Semlitsch 1988, Liss et al 1995). The absence of Long-toed Salamanders in the stocked lakes of the Bighorn Crags appears significant, although this should be viewed with caution as the sample size of lakes without fish was low (n=4). Long-toed Salamanders may simply be a rare amphibian species in the Bighorn Crags regardless of fish stocking.

Our analyses of Spotted Frog distributions and fish presence appear more complex. Our finding that Spotted Frogs typically breed in fishless lakes and isolated wetlands are supportive of other studies on ranids in high mountain environments (Bradford 1989, Bahls 1990, Dudley and Embury 1995, Liss et al. 1995). This pattern suggests that habitat conditions such as adjacent isolated wetlands can act as frog refuges and may serve an important function in mediating the effects of fish predation. Several studies on larval salamander response to fish presence indicate that prey refuges can substantially reduce predation effects of fish (Petranka 1983, Semlitsch 1988, Sih et al. 1992). A more thorough investigation of environmental characteristics of both lake and wetland habitats may reveal correlations with observed distribution patterns not found in this study.

Further research into this area is needed to distinguish adequately between "natural" distribution patterns and those induced by the presence of introduced fish.

Adult Spotted Frogs occurred at 18 of 28 (64%) stocked lakes and 5 of 5 (100%) unstocked lakes although this difference was not statistically significant ($P=0.128$, $\alpha=0.008$). The presence of adult Spotted Frogs in lakes with fish, but the lack of breeding in these lakes generates many questions. For example: Why do adult frogs occur in lakes with fish but do not breed in these lakes? Where did the adult frogs in lakes with fish come from? Are lakes with fish used as seasonal foraging habitats for adult frogs or are the observed frogs merely a disappearing remnant population? The answers to these questions are important to understand what role fish may be playing on the local and regional distribution of amphibians in the Bighorn Crags and what impact fish may have on the overall persistence of amphibians in high mountain lake environments.

One potential problem with the interpretation of our data is the types of lakes we surveyed. The 28 lakes surveyed represent just over half the total number of lakes in the study area. The lakes surveyed were chosen based on stocking record information which created two potential problems in the analysis of our data. First, the information on the stocking records obtained from Idaho Department of Fish and Game were incomplete and the number of stocked lakes in our study was underestimated (only 5 of the expected 14 lakes were unstocked). Secondly, the lakes were not chosen at random, but were based on fish stocking data and accessibility. This inadvertently caused our study to inadequately sample smaller and often fishless lakes. Our analysis of the presence of fish in large versus small lakes (Table 9c) shows that fish occurred significantly more frequently in large lakes ($P=0.011$, $\alpha=0.05$), and thus our sample bias of larger lakes also biased for lakes with fish. This sample bias probably resulted in underestimating Long-toed Salamander occurrences as salamanders may occur more often in small and fishless lakes (Tables 7c,9b).

In the southern survey area, in particular, this bias towards larger lakes with fish may have influenced our results. The southern survey area contains many small lakes that

were not surveyed in 1994. In the northern survey area there are few small lakes and consequently almost all lakes in the northern survey area were included in this report. We now have detailed information on the southern survey area from a study in 1995 (Pilliod and Peterson, unpublished data). Most of the results from this study are consistent with 1994 findings reported here. Long-toed Salamanders occurred at many but not all small lakes without fish and thus distribution and abundance of this species was underestimated by the 1994 surveys. Both Long-toed Salamander and Spotted Frog reproduction was negatively correlated with fish presence indicating that isolated wetlands near stocked lakes and small, fishless lakes are critical for amphibian reproduction in the Bighorn Crags. Movement data from mark-recapture and radiotelemetry on Spotted Frogs indicates that frogs seasonally migrate to specific locations in their habitat and that certain lakes act as important hubs of activity and contain habitat resources critical to the larger population of frogs. These findings suggest that looking at frog populations lake by lake may be inadequate as individual lake populations may actually be interconnected and interdependent. Further investigations into this important relationship are in progress and will be documented in subsequent reports.

In conclusion, based on our findings during the summer of 1994, Long-toed Salamanders and Tailed Frogs appear to be relatively unabundant in the Bighorn Crags and their distributions limited. Spotted Frogs are widely distributed and abundant in some locations. The distributions of Spotted Frogs and Long-toed Salamanders in the Bighorn Crags are not explained by the physical, chemical, and biological (with the exception of fish) characteristics of the lake habitats surveyed. The effects of introduced fish on amphibian populations shows a strong relationship between the presence of fish and subsequent absence of amphibian reproduction. The reasons for this negative relationship are not yet clear and will require further investigation.

Current research in the Bighorn Crags (Pilliod and Peterson) is addressing this issue with detailed monitoring and experimental manipulations to identify the proximate causes and ultimate consequences of fish stocking on amphibian populations in high mountain environments. The results from this study and the work in progress will be available to

state and federal wilderness managers to help understand and manage high mountain wilderness lakes.

ACKNOWLEDGMENTS

We would like to thank the USDA Forest Service Intermountain Research Station for providing the financial support for this initial study. We would especially like to thank Russ Thurow, our primary contact and project supporter with the USDA-IRS. Field data were collected with assistance from Raymond Clark and Dan Duncan.

LITERATURE CITED

Bahls, P. F. 1990. Ecological Implications of Trout Introductions to Lakes of the Selway Bitteroot Wilderness, Idaho. M.S. Thesis, Oregon State University, Corvallis, OR. 85 pp.

Bahls, P. F. 1992. The status of fish populations and management of high mountain lakes in the western United States. Northwest Science **66**:183-193.

Beiswinger, R.E. 1986. An endangered species, the Wyoming Toad *Bufo hemiophrys baxteri* - the importance of an early warning system. Biological Conservation **37** (1986):59-71.

Blaustein, A.R., P.D. Hoffman, D.G. Hokit, J.M. Kiesecker, S.C. Walls, and J.B. Hays. 1994. UV repair and resistance to solar UV-B in amphibian eggs: a link to population declines? Proc. Natl. Acad. Sci. **91**:1791-1795.

Bradford, D.F. 1989. Allotopic distribution of native frogs and introduced fishes in high Sierra Nevada lakes of California: Implication of the negative effect of fish introductions. Copeia **1989**:775-778.

Bradford, D.F. 1991. Mass mortality and extinction in a high elevation population of *Rana muscosa*. Journal of Herpetology **25**:174-177.

Bradford, D.F., C. Swanson, and M.S. Gordon. 1992. Effects of low pH and aluminum on two declining species of amphibians in the Sierra Nevada, California. Journal of Herpetology **26**(4):369-377.

Bradford, D.F., F. Tabatabai, and D.M. Graber. 1993. Isolation of remaining populations of the native frog, *Rana muscosa*, by introduced fishes in Sequoia and Kings Canyon National Parks, California. Conservation Biology **7**:882-888.

Collins, J.T. 1990. Standard common and current scientific names for North American amphibians and reptiles. Society for the Study of Amphibians and Reptiles: Herpetological Circular No. 19.

Corn, P.S. and J.C. Fogelman. 1984. Extinction of montane populations of the northern leopard frog *Rana pipiens* in Colorado. Journal of Herpetology **18**:147-152.

Corn, P.S. and F.A. Vertucci. 1992. Description risk assessment of the effects of acidic deposition on Rocky Mountain amphibians. Journal of Herpetology **26**:361-369.

Cowardin, L.W., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife, Biological Services Program, FWS/OBS-79/31, 131 pp.

Crump, M.L. and N.J. Scott Jr. 1994. Visual encounter surveys. In *Measuring and monitoring biological diversity: Standard methods for amphibians.* Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L. C. Hayek, and M.S. Foster (Eds.), Smithsonian Institution Press, Washington, D.C., pp. 84-92.

Dudley, T. and M. Embury. 1995. Non-indigenous species in wilderness areas: The status and impacts of livestock and game species in designated wilderness in California. Pacific Institute for Studies in Development, Environment, and Security, Oakland, CA., 38 pp.

Fellers, G.M. and C.A. Drost. 1993. Disappearance of the Cascades frog *Rana cascadae* at the southern end of its range, California, U.S.A. Biological Conservation **65**:177-181.

Figiel Jr., C.R., and R.D. Semlitsch. 1990. Population variation in survival and metamorphosis of larval salamanders (*Ambystoma maculatum*) in the presence and absence of fish predation. Copeia **1990** (3):818-826.

Hayes, M.P. and M.R. Jennings. 1986. Decline of ranid frog species in western North America: Are bullfrogs (*Rana catesbeiana*) responsible? Journal of Herpetology **20**:490-509.

Kats, L.B., J.W. Petranka, and S. Andrew. 1988. Antipredator defenses and the persistence of amphibian larvae with fishes. Ecology **69**:1865-1870.

Keppel, G. 1991. Design and Analysis: A Research's Handbook, 3rd edition. Prentice Hall, Upper Saddle River, NJ.

Liss, W.J., G.L. Larson, E. Deimling, L. Ganio, R. Gresswell, R. Hoffman, M. Kiss, G. Lomnicky, C.D. McIntire, R. Truitt, and T. Tyler. 1995. Ecological effects of stocked trout in naturally fishless high mountain lakes, North Cascades National Park Service Complex, WA, USA. Technical report NPS/PNROSU/NRTR-95-03, 285 pp.

Nussbaum, R.A., E.D. Brodie, and R.M. Storm. 1983. Amphibians and Reptiles of the Pacific Northwest. University of Idaho Press, Moscow, ID, 332 pp.

Petranka, J.W. 1983. Fish predation: A factor affecting the spatial distribution of a stream-breeding salamander. Copeia **1983**:624-628.

Semlitsch, R.D. 1988. Allotopic distribution of two salamanders: Effects of fish predation and competitive interactions. Copeia **1988**:290-298.

Sherman, C.K. and M.L. Morton. 1993. Population declines of Yosemite toads in the eastern Sierra Nevada of California. Journal of Herpetology **27**:186-198.

Sih, A., L.B. Kats, and R.D. Moore. 1992. Effects of predatory sunfish on the density, drift, and refuge use of stream salamander larvae. Ecology **73** (4):1418-1430.

Sokal, R.R., and F.J. Rohlf. 1995. Biometry: The principles and practice of statistics in biological research, 3rd edition. W.H. Freeman and Company, New York.

Taylor, J. 1983. Orientation and flight behavior of a neotenic salamander (*Ambystoma gracile*) in Oregon. Am. Midl. Nat. **109**:40-49.

Turner, F.B., 1962. An analysis of geographic variation and distribution of *Rana pretiosa*. Am. Philosophical Society Yearbook **1962**:325-328.

Voris, H.K. and J.P. Bacon, Jr. 1966. Differential predation on tadpoles. Copeia **1966**:594-598.

Common Name	Scientific Name	Status	Distribution*	Estimated Abundance*	Voucher	Successful Sampling Techniques	Comments
Confirmed							
Spotted Frog	*Rana pretiosa*	SSC-C, C2, BLM-S, FSR4-S	widespread	Abundant-Common	photo	visual search, dip net, incidental	tadpoles, metamorphs, juveniles, adults
Long-toed Salamander	*Ambystoma macrodactylum*		intermediate	Abundant-Variable	photo	visual search, dip net, incidental	larvae, adults
Tailed Frog	*Ascaphus truei*	C2	limited	Uncommon	photo	visual search & dip net	adults only
Western Toad	*Bufo boreas*	SSC-C, BLM-S	single site	Rare	specimen	visual search, incidental	tadpoles, metamorphs
Western Terrestrial Garter Snake	*Thamnophis elegans*		2 sites	Rare	photo	visual search, incidental	juvenile, adult
Possible							
Idaho Giant Salamander	*Dicamptodon aterrimus*						
Pacific Chorus (=Tree) Frog	*Pseudacris (= Hyla) regilla*						
Western Chorus Frog	*Pseudacris triseriata*						
Rubber Boa	*Charina bottae*						
Common Garter Snake	*Thamnophis sirtalis*						
Classification Information:							
Names based on Collins (1990)		from Idaho Conservation Data Center	Widespread	Abundant	Museum specimen	Techniques Employed	
			Intermediate	Common	Photograph	Incidental Observations	
Confirmed - voucher or reliable observation		IDFG Species of Special Concern	Limited	Uncommon		Visual Search	
Probable - within range; suitable habitat		SSC A = Priority Species		Rare		Aural Search	
Possible - range nearby; suitable habitat		SSC B = Peripheral Species	* based on our sampling			Netting	
		SSC C = Undetermined Status Species				Electroshocking (NMFS)	
		C1/C2 = USFWS Category 1/2 Candidate Species for T&E Species					
		BLM = Bureau of Land Mangement					
		FSR1/4 = Forest Service Region 1/4					
		S = Sensitive Species					

Table 1. Summary of occurrences of amphibians and reptiles of the Bighorn Crags, Frank Church River of No Return Wilderness. Updated: 5-10-96

		AMPHIBIAN SURVEY DATA:				FISH SURVEY DATA:
SITE #	LOCALITY	RAPR ADULT	RAPR TADPOLE	AMMA ADULT	AMMA LARVAE	FISH OBSERVED
1	Glacier Lake	0	0	0	0	Yes
2	Pothole Lake	7	2	0	0	Yes
3	Big Clear Lake	1	0	0	0	Yes
4	Gooseneck Lake	0	0	0	0	Yes
5	Crater Lake	0	0	0	0	Yes
6	Mirrow Lake	9	0	0	0	Yes
7	Gentian Lake	15	10	0	1 *	Yes
8	Birdbill Lake	1	0	0	0	Yes
9	Shoban	1	0	0	0	Yes
10	Sheepeater Lake	0	0	0	0	Yes
11	Wilson Lake	0	0	0	0	Yes
12	Harbor Lake	0	0	0	0	Yes
13	Heart Lake	0	0	0	0	Yes
14	Welcome Lake	9	13	0	0	Yes
15	Skyhigh Lake	19	0	0	0	Yes
16	Turquoise Lake	0	0	0	0	Yes
17	Echo Lake	0	0	0	0	Yes
18	Reflection Lake	10	0	0	0	Yes
19	Twin Cove Lake	4	0	0	0	Yes
20	Fawn Lake	8	500+	0	0	No
21	Doe Lake	1	0	0	0	Yes
22	Buck Lake	0	0	0	0	Yes
23	Tip Top Lake	600+	10	1	5	No
24	Unnamed (NW Ramshorn)	13	1	2	1	No
25	Ramshorn Lake	25	0	0	0	Yes
26	Paragon Lake	77	0	0	0	Yes
27	Alpine Lake	18	40	0	5	No
28	Unnamed (SE Alpine)	43	100+	0	30+	No

Table 2. Summary of amphibian and fish survey data collected in July and August 1994. Numbers represent approximate number individuals observed in each age group for Spotted Frogs (RAPR) and Long-toed Salamanders (AMMA). * = in adjacent wetland separate from lake.

		LAKE	NWI				NWI	ISOLATED		LONG-TOED	SPOTTED
SITE #	LAKE NAME	TYPE	SYSTEM	SIZE	DEPTH	NWI CLASS	SUBCLASS	WETLANDS	TROUT	SALAMANDER	FROG
27	Alpine	1	Palustrine	< 8 ha	< 2 m	unconsolidated	mud	absent	absent	la	ad & la
20	Fawn	1	Palustrine	< 8 ha	< 2 m	unconsolidated	mud	absent	absent	absent	ad & la
23	Tip Top	1	Palustrine	< 8 ha	< 2 m	unconsolidated	mud	absent	absent	ad & la	ad & la
24	Unnamed (NW Ramshorn)	2	Lacustrine	< 8 ha	> 2 m	unconsolidated	cobble-gravel	absent	absent	ad & la	ad & la
28	Unnamed (SE Alpine)	2	Lacustrine	< 8 ha	> 2 m	rocky	rubble (boulder)	absent	absent	la	ad & la
7	Gentian	3	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	present	present	la	ad & la
2	Pothole	3	Lacustrine	< 8 ha	> 2 m	unconsolidated	mud	present	present	absent	ad & la
25	Ramshorn	3	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	present	present	absent	ad
14	Welcome	3	Lacustrine	< 8 ha	> 2 m	unconsolidated	mud	present	present	absent	ad & la
3	Big Clear	4	Lacustrine	>8 ha	> 2 m	unconsolidated	sand	absent	present	absent	ad
8	Birdbill	4	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	absent	present	absent	ad
21	Doe	4	Lacustrine	< 8 ha	> 2 m	unconsolidated	mud	absent	present	absent	ad
6	Mirrow	4	Lacustrine	< 8 ha	> 2 m	unconsolidated	mud	absent	present	absent	ad
26	Paragon	4	Lacustrine	< 8 ha	> 2 m	unconsolidated	mud	absent	present	absent	ad
18	Reflection	4	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	absent	present	absent	ad
9	Shoban	4	Lacustrine	< 8 ha	> 2 m	unconsolidated	cobble-gravel	absent	present	absent	ad
15	Skyhigh	4	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	absent	present	absent	ad
19	Twin Cove	4	Lacustrine	< 8 ha	> 2 m	unconsolidated	mud	absent	present	absent	ad
22	Buck	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	mud	absent	present	absent	absent
5	Crater	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	cobble-gravel	absent	present	absent	absent
17	Echo	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	mud	absent	present	absent	absent
1	Glacier	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	cobble-gravel	absent	present	absent	absent
4	Gooseneck	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	absent	present	absent	absent
12	Harbor	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	absent	present	absent	absent
13	Heart	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	absent	present	absent	absent
10	Sheepeater	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	cobble-gravel	absent	present	absent	absent
16	Turqouise	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	cobble-gravel	absent	present	absent	absent
11	Wilson	5	Lacustrine	< 8 ha	> 2 m	unconsolidated	sand	absent	present	absent	absent

Table 3. Lake classification and species occurrence for each lake surveyed between 29 July and 17 August 1994. Lakes types determined by the following: (1) Small, shallow, fishless lakes with breeding amphibians; (2) Small, deep, fishless lakes with breeding amphibians; (3) Small, deep lakes with fish, with amphibians breeding in isolated habitat; (4) Small or large, deep lakes with fish, and with adult frogs; (5) Small, deep lakes with fish, without amphibians; (6) Unsurveyed Lakes. Age Classes: ad=adult; la=larvae.

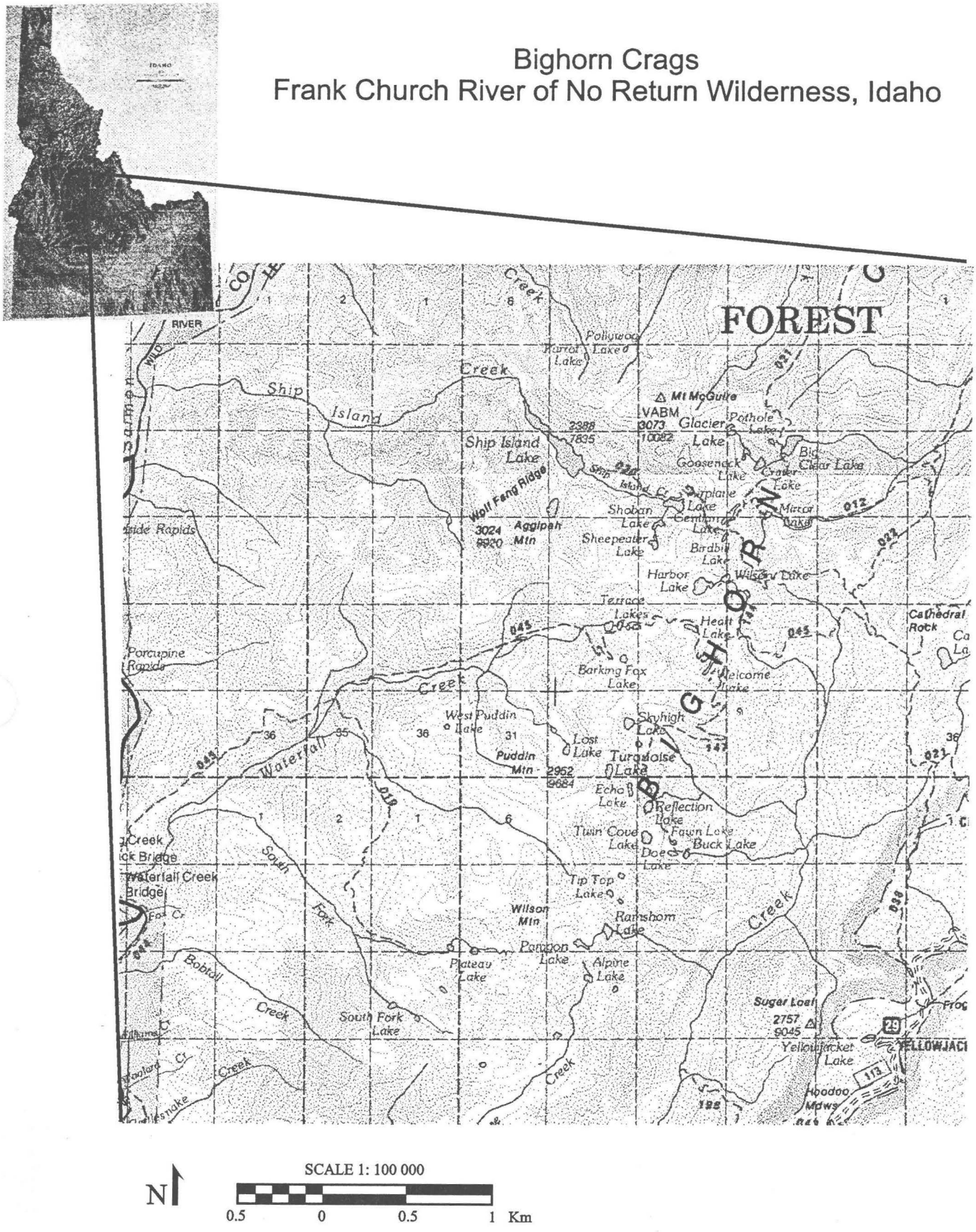
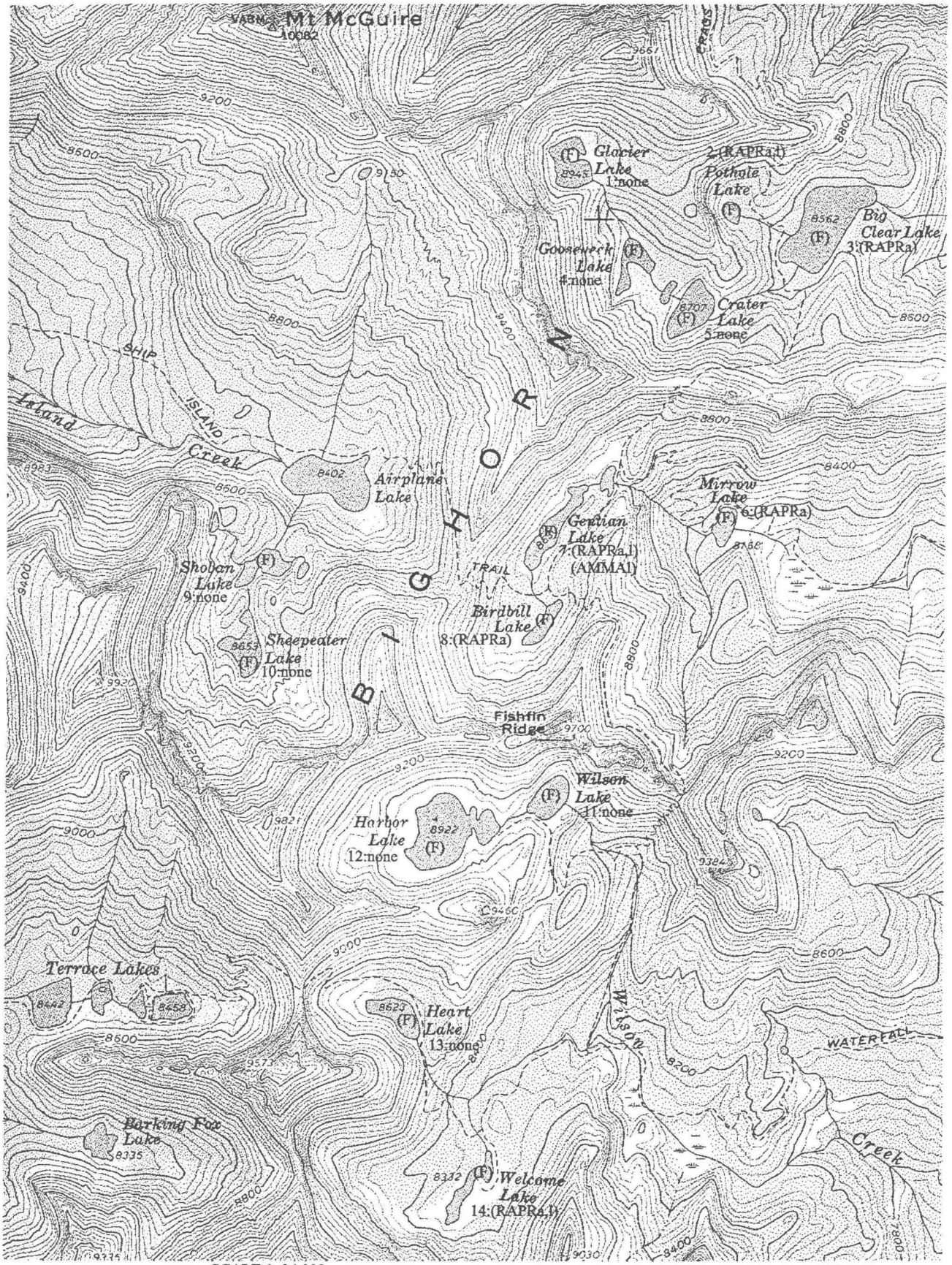


Figure 1. Map of the study area in the Bighorn Crags of the Frank Church-River of No Return Wilderness.

Figure 2a. Map of the northern survey area in the Bighorn Crags, 14 - 17 August 1994. Red characters refer to the site number and species present. F=Fish Observed; RAPRa,l=Spotted Frog adult, larvae *(Rana pretiosa);* AMMAa,l=Long-toed Salamander adult, larvae *(Ambystoma macrodactylum)*



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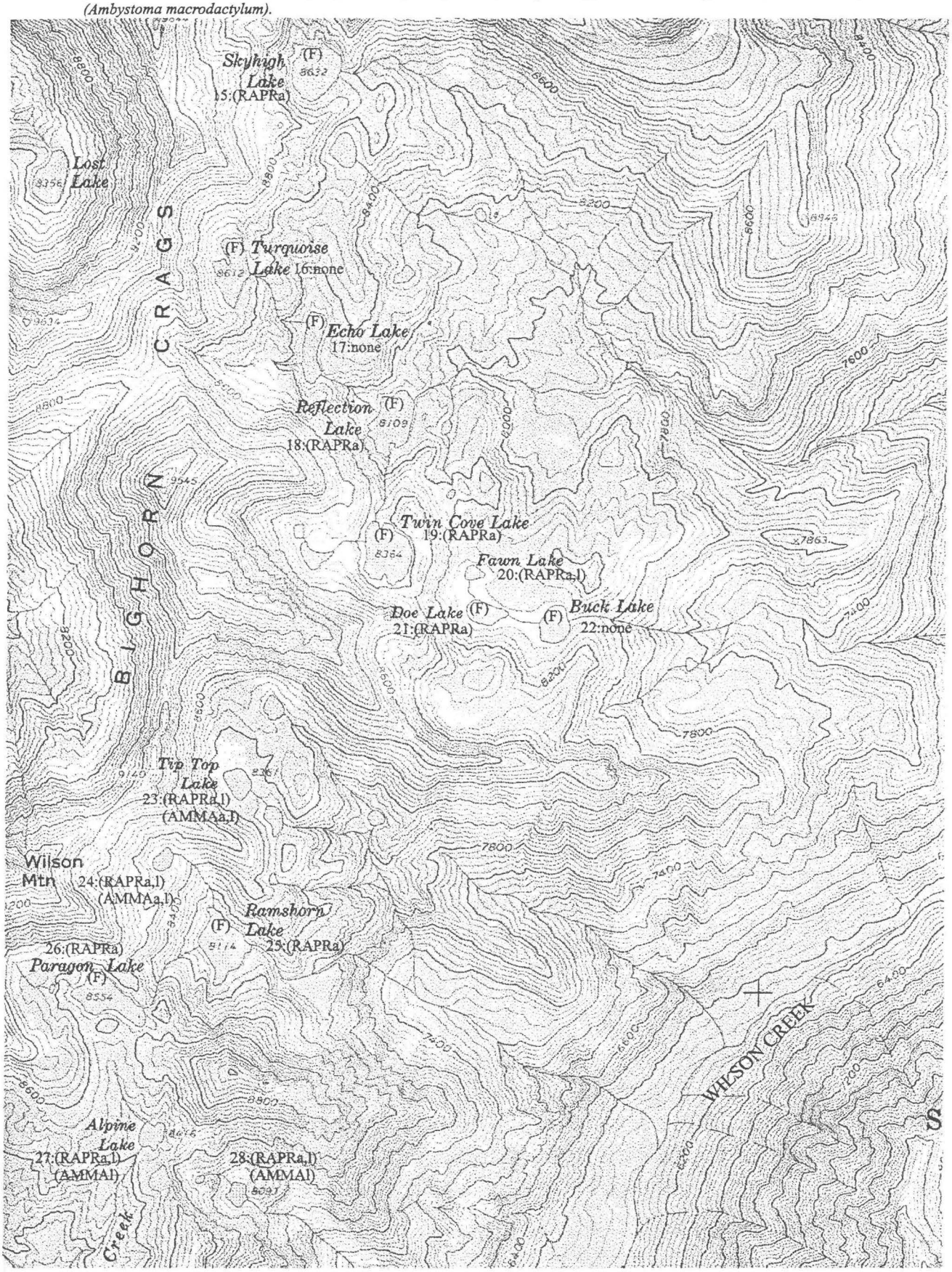
0.5 0 0.5 1 Km

MT. McGUIRE QUADRANGLE

LEMHI COUNTY, IDAHO

Figure 2b. Map of the southern survey area in the Bighorn Crags, 29 July - 1 August 1994. Red characters refer to the site number and species present. F=Fish Observed; RAPRa,l=Spotted Frog adult, larvae *(Rana pretiosa);* AMMAa,l=Long-toed Salamander adult, larvae *(Ambystoma macrodactylum).*



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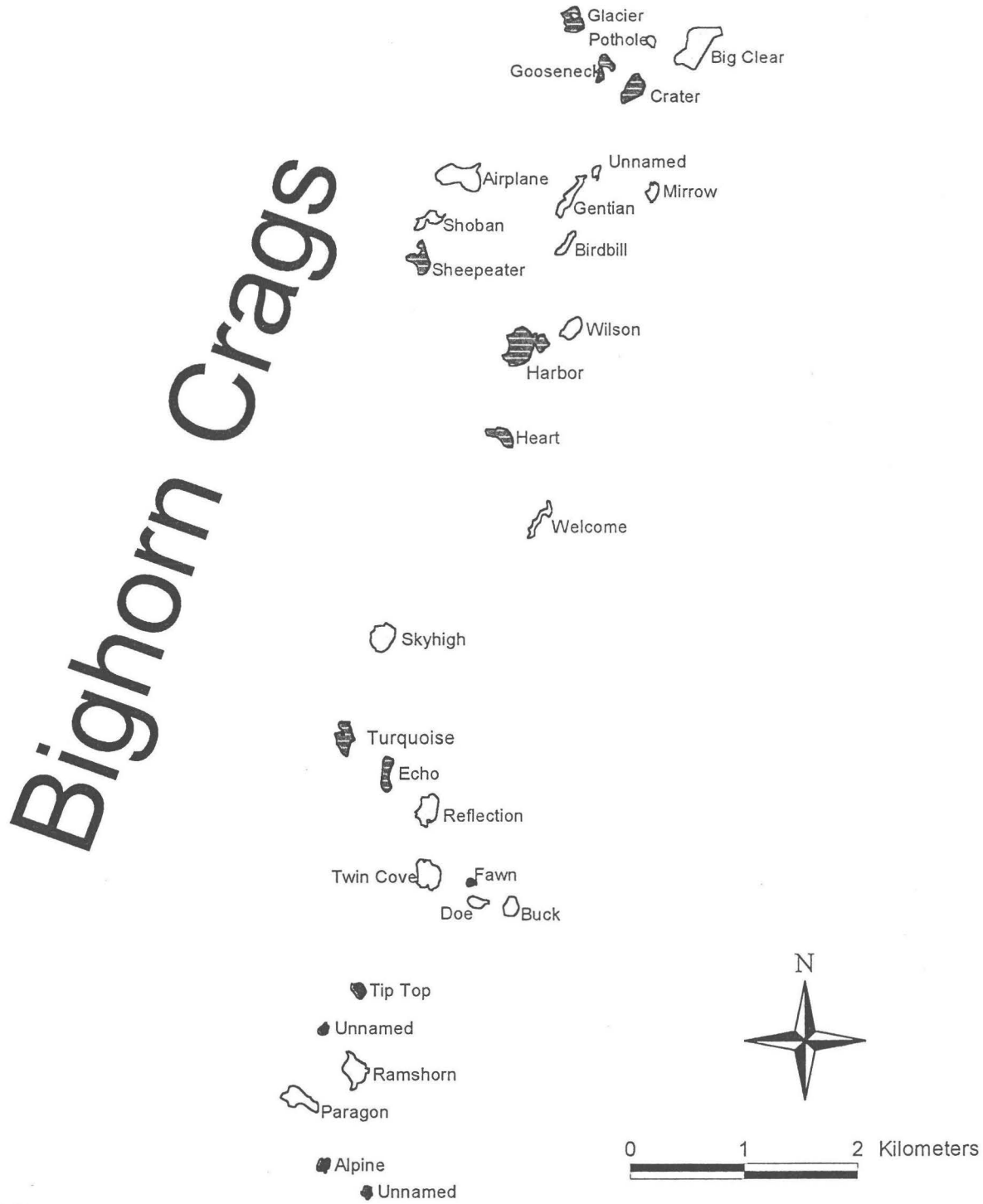
HOODOO MEADOWS QUADRANGLE

LEMHI COUNTY, IDAHO



Bighorn Crags

- Type 1: Small, shallow, fishless lakes with breeding amphibians
- Type 2: Small, deep, fishless lakes with breeding amphibians
- Type 3: Small, deep lakes with fish, with amphibians breeding in isolated habitat
- Type 4: Small or large, deep lakes with fish, and with adult frogs
- Type 5: Small, deep lakes with fish, without amphibians
- Unsurveyed lakes

Figure 3. Map of the lakes surveyed in July and August 1994. Lake type based on size (small:<1 ha, large:>1 ha), depth (shallow:<2 m, deep:>2 m), amphibian presence and/or breeding, fish presence, and isolated wetland occurrence.

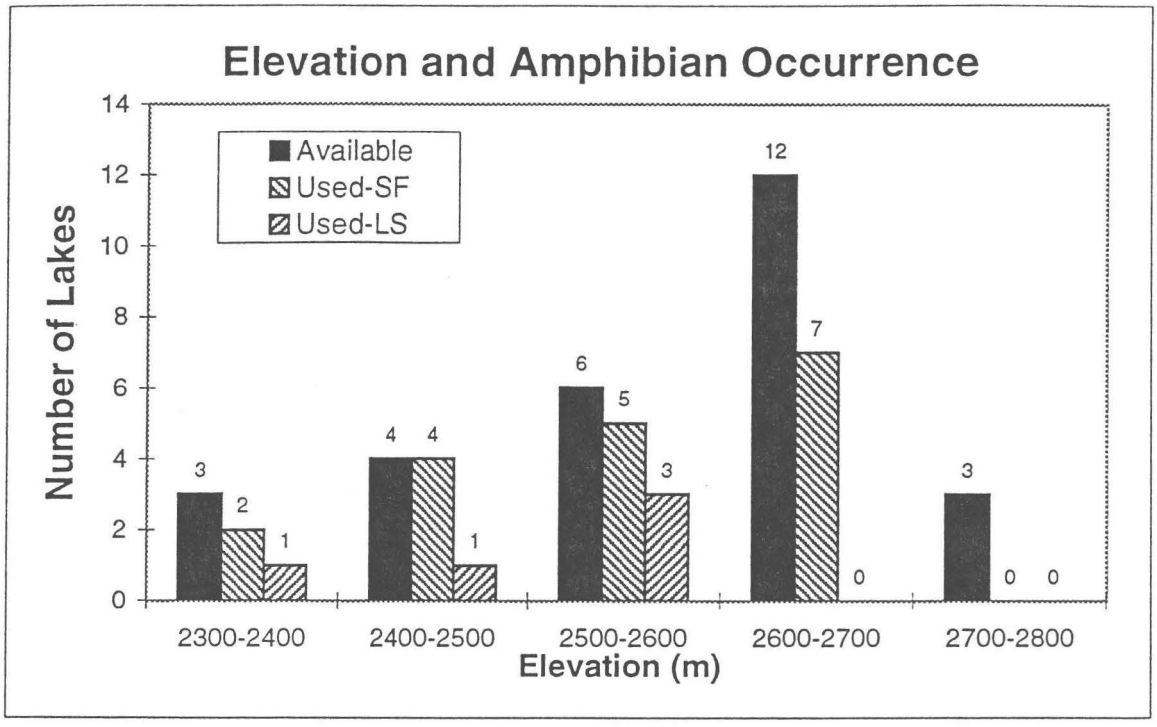


Figure 4. Comparison of lakes available and used by amphibians at different elevations in the Bighorn Crags study area. Spotted Frog adults (SF) and Long-toed Salamander larvae (LS) observations are based on visual surveys conducted July and August 1994.

	Lake Elevation (m)					
# Lakes:	2300-2400	2400-2500	2500-2600	2600-2700	2700-2800	Total
Spotted Frogs Found (Expected)	2 (1.9)	4 (2.6)	5 (3.9)	7 (7.7)	0 (1.9)	18
Spotted Frogs Not Found (Expected)	1 (1.1)	0 (1.4)	1 (2.1)	5 (4.3)	3 (1.1)	10
Total	3	4	6	12	3	28

Table 4a. Contingency table of the total number of lakes where Spotted Frogs were found versus not found over the range of lake elevations surveyed in the Bighorn Crags study area. There was no relationship between adult spotted frog occurrence and lake elevation (Fisher's Exact P=0.078, two-tailed, Bonferroni adjusted alpha=0.008).

	Lake Elevation (m)					
# Lakes:	2300-2400	2400-2500	2500-2600	2600-2700	2700-2800	Total
LT Salamanders Found (Expected)	1 (0.5)	1 (0.7)	3 (1.1)	0 (2.1)	0 (0.5)	5
LT Salamanders Not Found (Expected)	2 (2.5)	3 (3.3)	3 (4.9)	12 (9.9)	3 (2.5)	23
Total	3	4	6	12	3	28

Table 4b. Contingency table of the total number of lakes where Long-toed Salamanders were found versus not found over the range of lake elevations surveyed in the Bighorn Crags study area. There was no relationship between Long-toed Salamander occurrence and lake elevation (Fisher's Exact P=0.045, two-tailed, Bonferroni adjusted alpha=0.008).

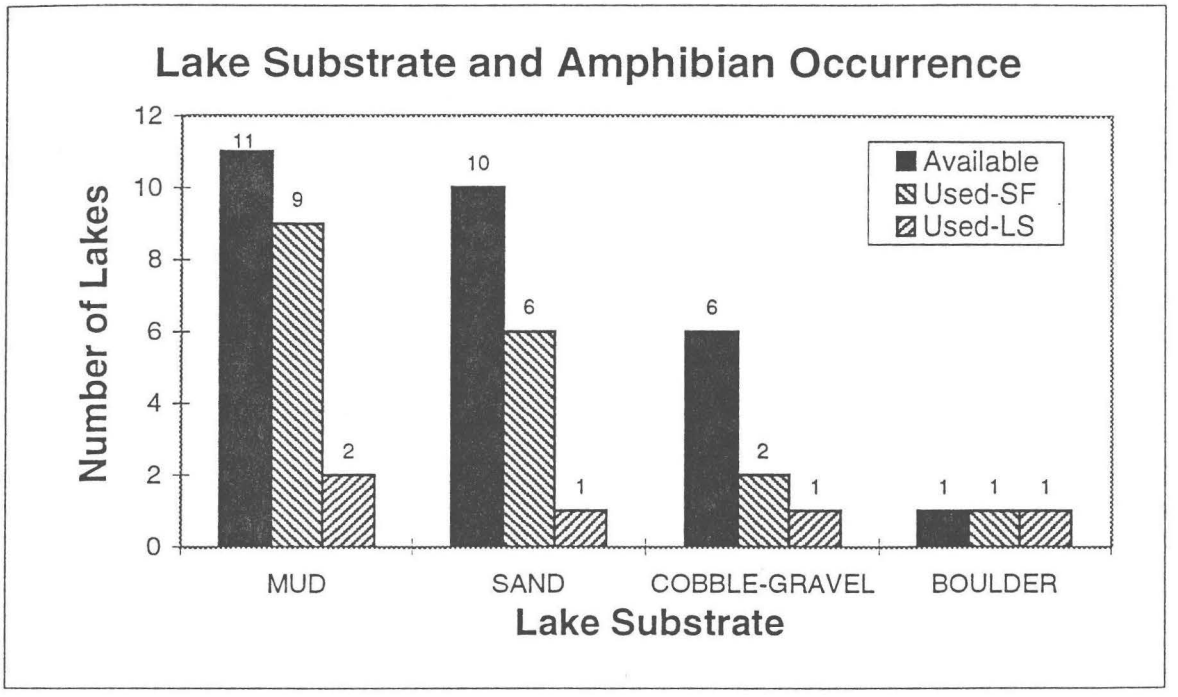


Figure 5. Comparison of lakes available and used by amphibians with different aquatic substrate types in the Bighorn Crags study area. Spotted Frog adults (SF) and Long-toed Salamander larvae (LS) observations are based on visual surveys conducted July and August 1994.

	Lake Substrate				
# Lakes:	Mud	Sand	Cobble	Boulder	Total
Spotted Frogs Found (Expected)	9 (7.1)	6 (6.4)	2 (3.9)	1 (0.6)	18
Spotted Frogs Not Found (Expected)	2 (3.9)	4 (3.6)	4 (2.1)	0 (0.4)	10
Total	11	10	6	1	28

Table 5a. Contingency table of the total number of lakes where Spotted Frogs were found versus not found with different aquatic substrate types in the Bighorn Crags study area. There was no relationship between spotted frog occurrence and lake substrate (Fisher's Exact P=0.186, two-tailed, Bonferroni adjusted alpha=0.008).

	Lake Substrate				
# Lakes:	Mud	Sand	Cobble	Boulder	Total
LT Salamanders Found (Expected)	2 (2.0)	1 (1.8)	1 (1.1)	1 (0.2)	5
LT Salamanders Not Found (Expected)	9 (9.0)	9 (8.2)	5 (4.9)	0 (0.8)	23
Total	11	10	6	1	28

Table 5b. Contingency table of the total number of lakes where Long-toed Salamanders were found versus not found with different aquatic substrate types in the Bighorn Crags study area. There was no relationship between Long-toed Salamander occurrence and lake substrate (Fisher's Exact P=0.365, two-tailed, Bonferroni adjusted alpha=0.008).

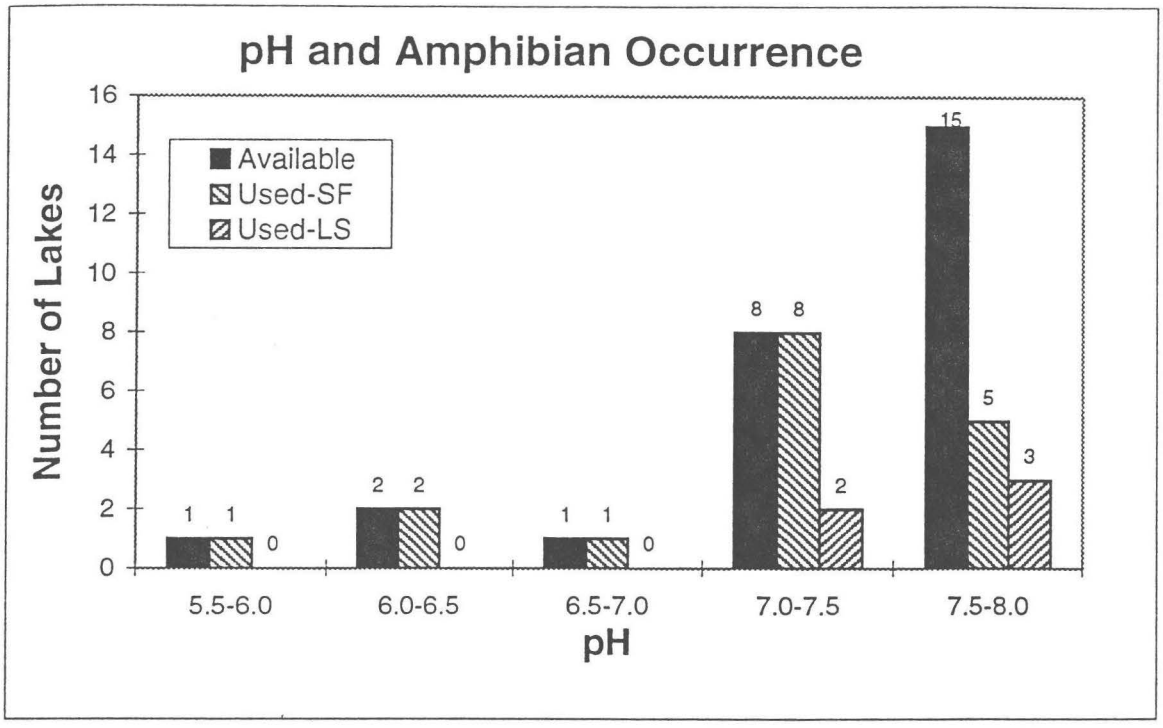


Figure 6. Comparison of lakes available and used by amphibians over the range of measured pH levels in the Bighorn Crags study area. Spotted Frog adults (SF) and Long-toed Salamander larvae (LS) observations are based on visual surveys conducted July-August 1994.

	Lake Water pH					
# Lakes:	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	Total
Spotted Frogs Found (Expected)	1 (0.6)	2 (1.3)	1 (0.6)	8 (5.0)	5 (9.4)	17
Spotted Frogs Not Found (Expected)	0 (0.4)	0 (0.7)	0 (0.4)	0 (3.0)	10 (5.6)	10
Total	1	2	1	8	15	27

Table 6a. Contingency table of the total number of lakes where Spotted Frogs were found versus not found over the range of lake water pH measured in the Bighorn Crags study area. There was a significant relationship between spotted frog occurrence and lake water pH (Fisher's Exact P=0.002, two-tailed, Bonferroni adjusted alpha=0.008). No pH data for Shoban Lake.

	Lake Water pH					
# Lakes:	5.5-6.0	6.0-6.5	6.5-7.0	7.0-7.5	7.5-8.0	Total
LT Salamanders Found (Expected)	0 (0.2)	0 (0.4)	0 (0.2)	2 (1.5)	3 (2.8)	5
LT Salamanders Not Found (Expected)	1 (0.8)	2 (1.6)	1 (0.8)	6 (6.5)	12 (12.2)	22
Total	1	2	1	8	15	27

Table 6b. Contingency table of the total number of lakes where Long-toed Salamanders were found versus not found over the range of lake water pH measured in the Bighorn Crags study area. There was no relationship between Long-toed Salamander occurrence and lake water pH (Fisher's Exact P=1.000, two-tailed, Bonferroni adjusted alpha=0.008). No pH data for Shoban Lake.

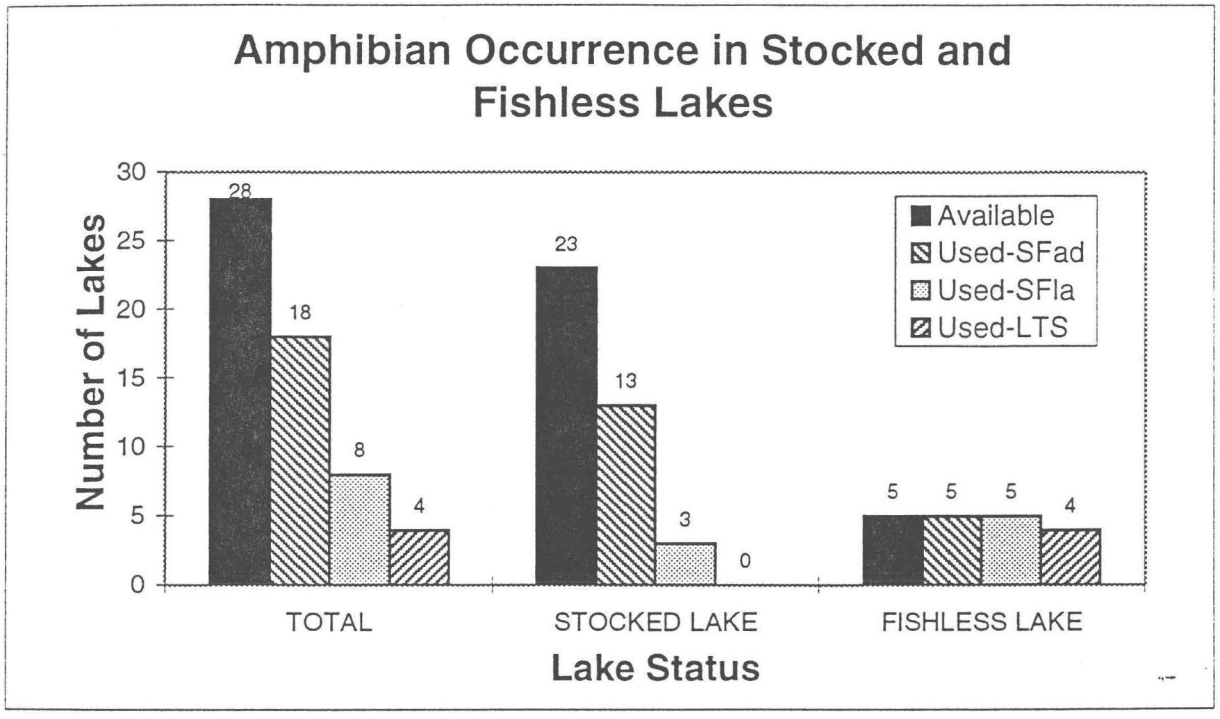


Figure 7. Comparison of the occurrence of Spotted Frog adults (SFad) and larvae (SFla), and Long-toed Salamander adults and larvae (LTS) in stocked versus fishless lakes. The "Total" bar-graph is the sum of both stocked and fishless lakes. All data based on visual observations conducted in July and August 1994

	Stocked Lakes	Fishless Lakes	Total
Lakes with Spotted Frog adults	13 (14.8)	5 (3.2)	18
Lakes without Spotted Frog adults	10 (8.2)	0 (1.8)	10
Total	23	5	28

Table 7a. Two by two contingency table analysis of lakes with or without Spotted Frogs adults in fish or fishless lakes. There was no relationship between adult frog occurrence and fish (Fisher's Exact P=0.128, two-tailed, Bonferroni adjusted alpha=0.008).

	Stocked Lakes	Fishless Lakes	Total
Lakes with Spotted Frog tadpoles	3 (6.6)	5 (1.4)	8
Lakes without Spotted Frog tadpoles	20 (16.4)	0 (3.6)	20
Total	23	5	28

Table 7b. Two by two contingency table analysis of lakes with or without Spotted Frogs tadpoles in fish or fishless lakes. There was a negative relationship between the occurrence of fish and larval frogs (Fisher's Exact P<0.001, two-tailed, Bonferroni adjusted alpha=0.008).

FISH AND AMPHIBIAN OCCURRENCE (CONT.)

	Stocked Lakes	Fishless Lakes	Total
Lakes with Long-toed Salamanders	0 (3.3)	4 (0.7)	4
Lakes without Long-toed Salamanders	23 (19.7)	1 (4.3)	24
Total	23	5	28

Table 7c. Two by two contingency table analysis of lakes with or without Long-toed Salamanders in fish or fishless lakes. There was a negative relationship between the occurrence of fish and larval salamanders (Fisher's Exact P<0.001, two-tailed, alpha=0.008).

EMERGENT VEGETATION AND AMPHIBIAN OCCURRENCE

	Veg Present	Veg Absent	Total
Lakes with Spotted Frog adults	6 (5.1)	12 (12.9)	18
Lakes without Spotted Frog adults	2 (2.9)	8 (7.1)	10
Total	8	20	28

Table 8a. Two by two contingency table analysis of lakes with or without Spotted Frogs versus lakes with (>5%) or without (<5%) shoreline emergent vegetation. There was no relationship between frog occurrence and aquatic vegetation (Fisher's Exact P=0.669, two-tailed, alpha=0.008).

	Veg Present	Veg Absent	Total
Lakes with Long-toed Salamanders	2 (1.4)	3 (3.6)	5
Lakes without Long-toed Salamanders	4 (6.6)	19 (16.4)	23
Total	6	22	28

Table 8b. Two by two contingency table analysis of lakes with or without Long-toed Salamanders in lakes with (>5%) or without (<5%) emergent vegetation. There was no relationship between the occurrence of salamanders and emergent vegetation (Fisher's Exact P=0.606, two-tailed, Bonferroni adjusted alpha=0.008).

LAKE SIZE AND SPECIES OCCURRENCE

	Large Lake	Small Lake	Total
Lakes with Spotted Frog adults	14 (15.4)	4 (2.6)	18
Lakes without Spotted Frog adults	10 (8.6)	0 (1.4)	10
Total	24	4	28

Table 9a. Two by two contingency table analysis of lakes with or without Spotted Frogs in large or small lakes. There was no relationship between the occurrence of frogs and lake size was (Fisher's exact P=.265, two-tailed, Bonferroni adjusted alpha=0.008).

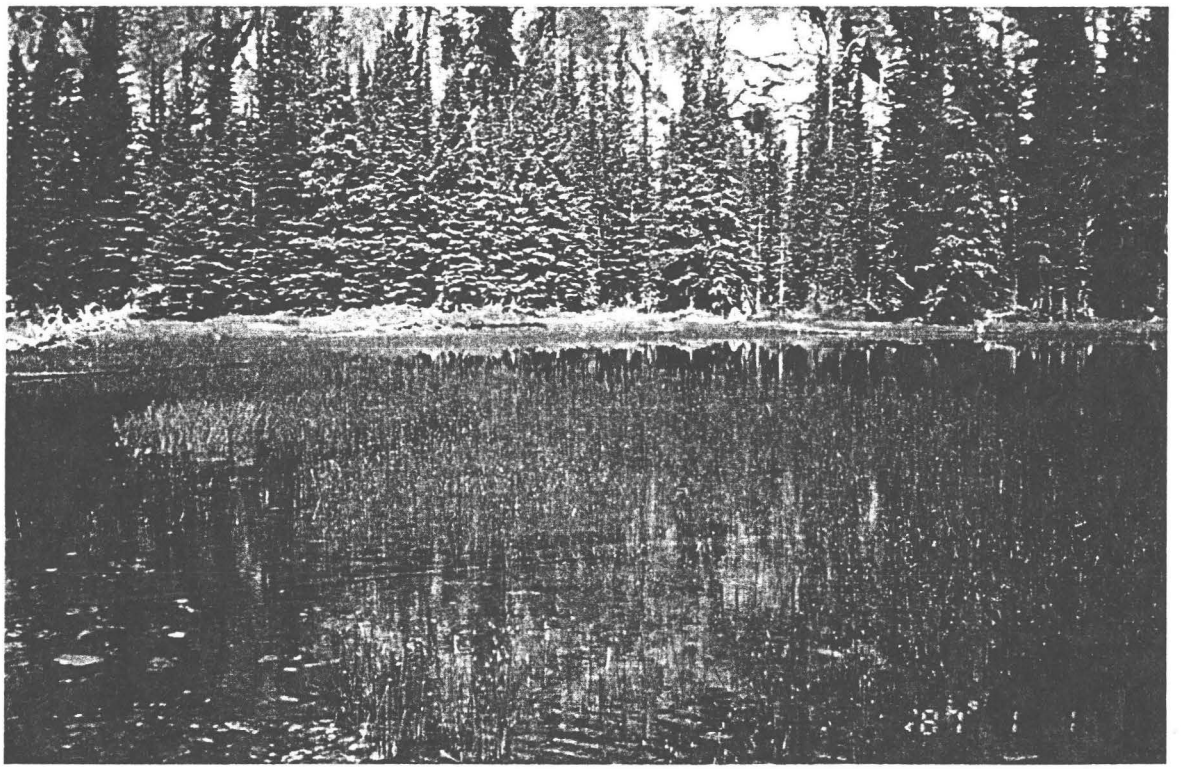
	Large Lake	Small Lake	Total
Lakes with Long-toed Salamanders	3 (4.3)	2 (0.7)	5
Lakes without Long-toed Salamanders	21 (19.7)	2 (3.3)	23
Total	24	4	28

Table 9b. Two by two contingency table analysis of lakes with or without Long-toed Salamanders in large or small lakes. There was a significant relationship between salamander occurrence and lake size (Fisher's Exact P=.135, two-tailed, Bonferroni adjusted alpha=0.008).

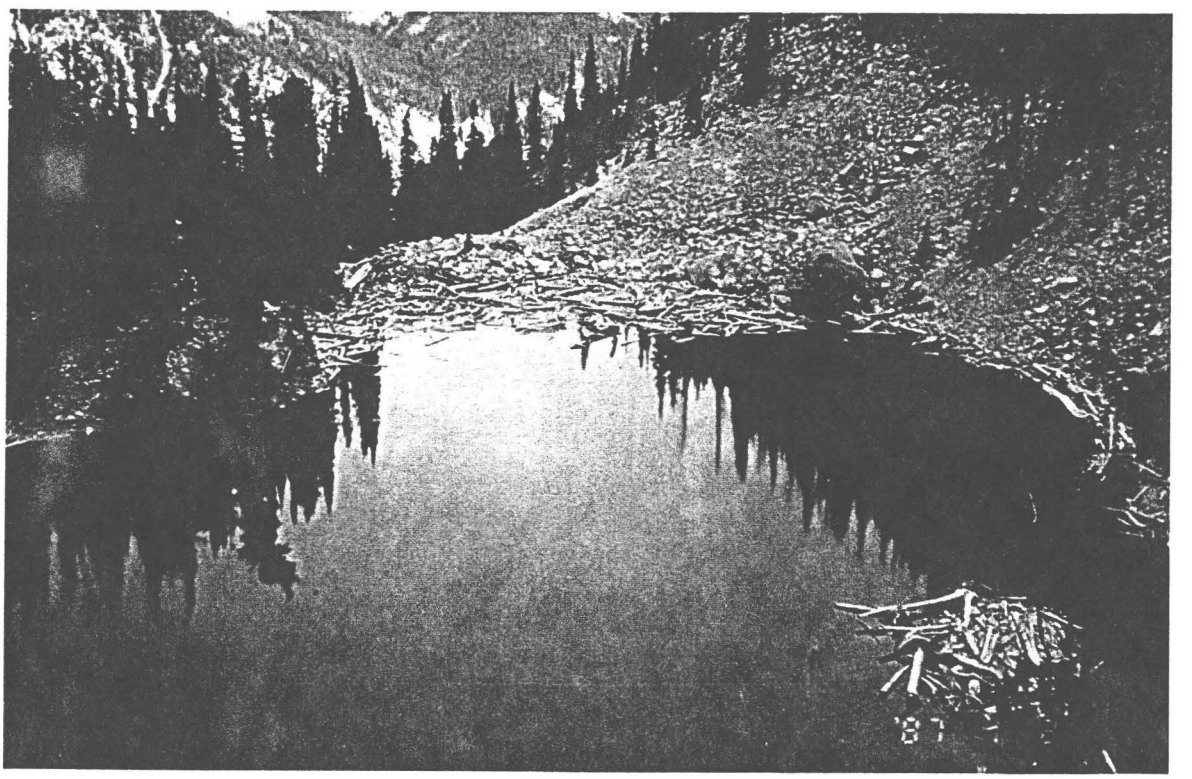
	Large Lake	Small Lake	Total
Lakes with Fish	22 (19.7)	1 (3.3)	23
Lakes without Fish	2 (4.3)	3 (0.7)	5
Total	24	4	24

Table 9c. Two by two contingency table analysis of lakes with or without stocked trout in large or small lakes. There was a significant relationship between the occurrence of fish and lake size (Fisher's Exact P=.011, two-tailed, alpha=0.05).

Appendix A: Photographic examples of physico-biological lake types.

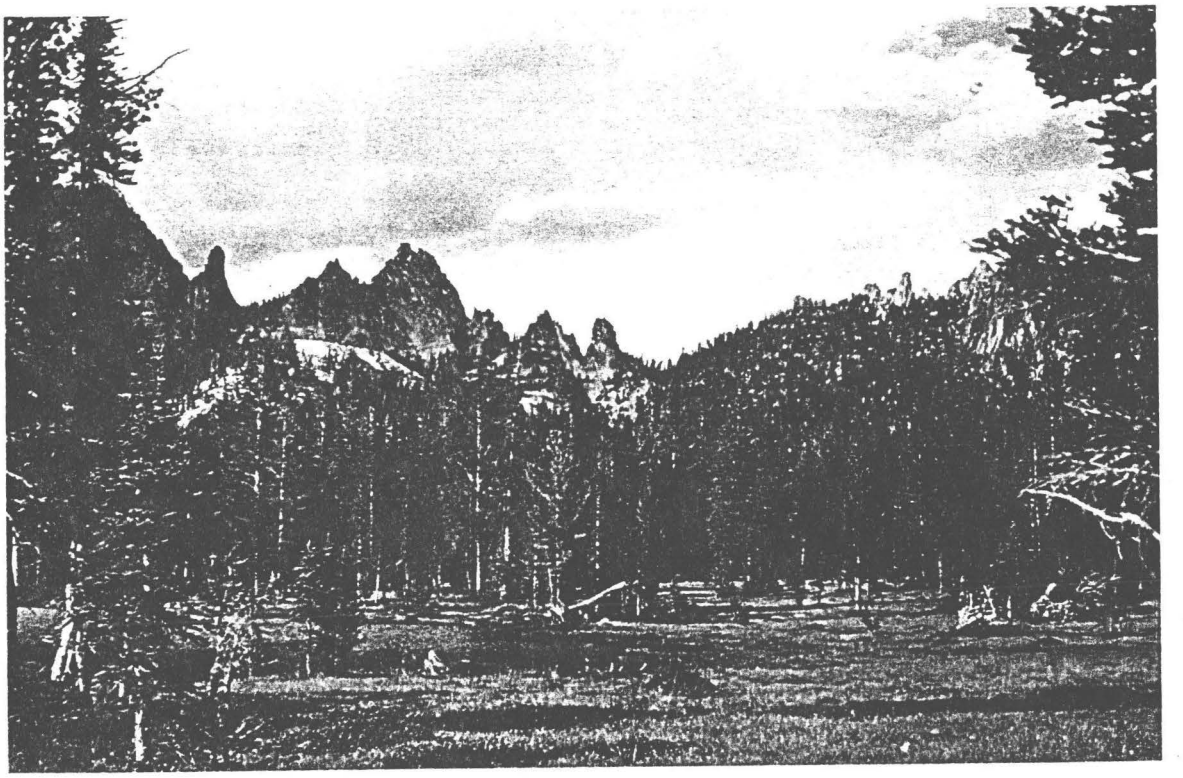


Lake Type 1: Small, shallow, fishless lakes with breeding amphibians.
Fawn Lake, Hoodoo Meadows Quadrangle, Bighorn Crags, Idaho.

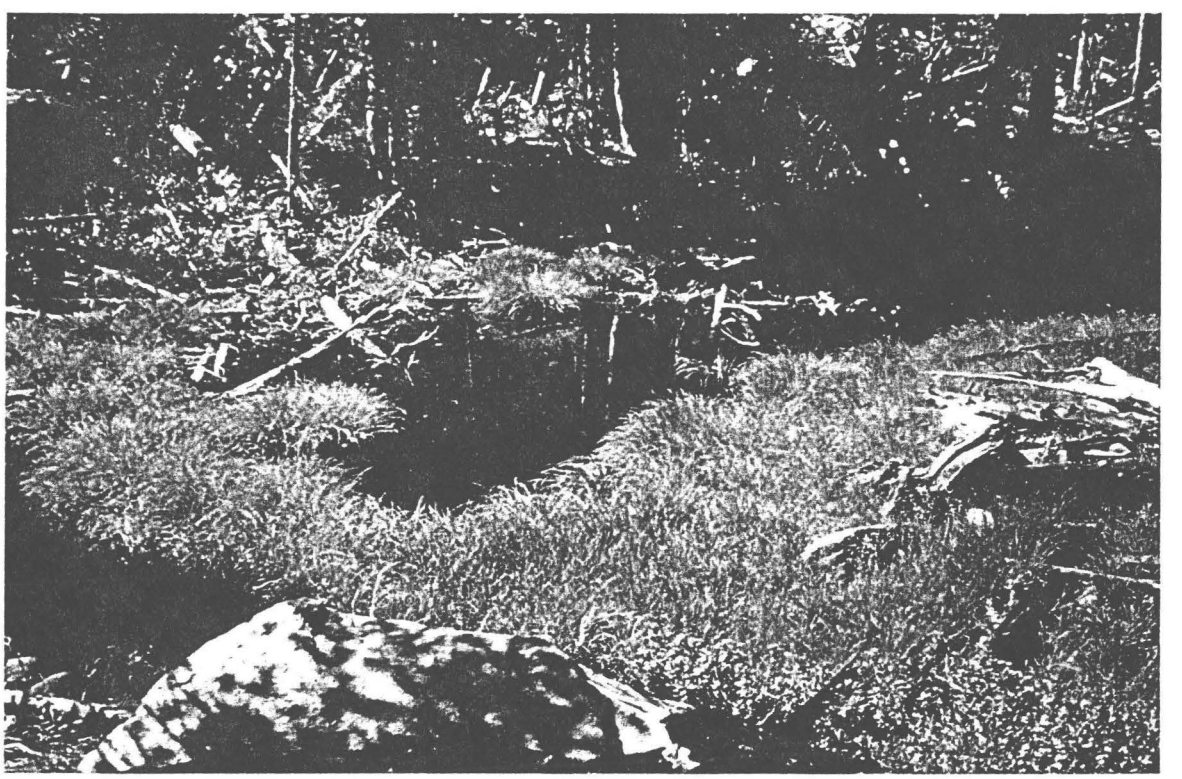


Lake Type 2: Small, deep, fishless lakes with breeding amphibians.
Unnamed Lake (0.3 km SE Alpine Lake), Hoodoo Meadows Quadrangle, Bighorn Crags, Idaho.

Appendix A: Photographic examples of physico-biological lake types.



Lake Type 3: Small, deep lakes with fish, with amphibians breeding in isolated habitat adjacent to lake.
Welcome Lake, Mt. McGuire Quadrangle, Bighorn Crags, Idaho.



Isolated Wetland of Lake Type 3.
Isolated wetland next to Ramshorn Lake, Hoodoo Meadows Quadrangle, Bighorn Crags, Idaho.

Lake Type 4: Small or large, deep lakes with fish, and adult frogs only (no amphibian reproduction).
Crater Lake, Mt. McGuire Quadrangle, Bighorn Crags, Idaho.

Lake Type 5: Small, deep lakes with fish, without amphibians.
Birdbill Lake (part of Birdbill/Gentian complex), Mt. McGuire Quadrangle, Bighorn Crags, Idaho.

Appendix B. Data Form

AMPHIBIAN SURVEY DATA SHEET – US FISH & WILDLIFE SERVICE, 4512 McMURRAY AVE, FT. COLLINS, CO 80525-3400

(circle choice for shaded variables; supply value for others) (ver. 2/7)

DATE	BEGIN TIME	END TIME	OBSERVERS

LOCALITY

STATE	COUNTY	MAP NAME	OWNER	ELEVATION (circle scale) M FT

T	R	S	SECTION DESCRIPTION	UTM ZONE	NORTHING (or LAT)	EASTING (or LONG)

AMPHIBIAN AND/OR GARTER SNAKE SPECIES PRESENT (INDICATE NUMBERS IN CATEGORIES IF POSSIBLE)

CIRCLE METHOD AND INDICATE IF VOUCHER SPECIMEN WAS COLLECTED

SPECIES	ADULTS/JUVENILES	CALLING?	TADPOLES/LARVAE	EGG MASSES	METHOD:
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO
		Y N			VISUAL/AURAL ID DIP NET/SEINE HAND COLLECTED TRAPPED VOUCHER COLLECTED? YES NO

FISH PRESENT? YES ??? NO	FISH SPECIES:		
ENTIRE SITE SEARCHED? YES NO	IF NO, INDICATE AREA	METERS OF SHORELINE / M² OF HABITAT	

PHYSICAL AND CHEMICAL ENVIRONMENT (CHEMISTRY VARIABLES OPTIONAL - USE EXTRA SPACES FOR ADDITIONAL MEASUREMENTS)

WEATHER: CLEAR	OVERCAST	RAIN	SNOW	WIND: CALM	LIGHT	STRONG

AIR TEMP (circle scale) °C °F	WATER TEMP (circle scale) °C °F	COLOR: CLEAR	STAINED	TURBIDITY: CLEAR	CLOUDY

pH	ANC			

SITE DESCRIPTION: (SKETCH SITE AND PUT ADDITIONAL COMMENTS ON BACK OF SHEET)
OMIT THIS SECTION IF DATA HAVE BEEN COLLECTED ON A PREVIOUS VISIT

ORIGIN: NATURAL	MAN-MADE	DRAINAGE: PERMANENT	OCCASIONAL	NONE

DESCRIPTION: PERMANENT LAKE/POND	TEMPORARY LAKE/POND	MARSH/BOG	STREAM	SPRING/SEEP	ACTIVE BEAVER POND	INACTIVE BEAVER POND

SITE LENGTH (M)	SITE WIDTH (M)	MAXIMUM DEPTH:	< 1 M	1 – 2 M	> 2 M

STREAM ORDER	1	2	3	4	5 +

PRIMARY SUBSTRATE:	SILT/MUD	SAND/GRAVEL	COBBLE	BOULDER/BEDROCK	OTHER

% OF POND/LAKE MARGIN WITH EMERGENT VEGETATION:	0	1 – 25	25 – 50	> 50

EMERGENT VEGETATION SPECIES (LIST IN ORDER OF ABUNDANCE)				

NORTH SHORELINE CHARACTERS:	SHALLOWS PRESENT	SHALLOWS ABSENT	EMERGENT VEG PRESENT	EMERGENT VEG ABSENT

DISTANCE (M) TO FOREST EDGE	FOREST TREE SPECIES:			

Appendix C. 1994 Bighorn Crags amphibian, fish, and lake survey data.

		LAKE SURVEY DATA:							GEOGRAPHIC DATA:				
SITE #	LOCALITY	DAY	MONTH	YEAR	BEGIN TIME	END TIME	DURATION (min)	OBSERVERS	MAP NAME	ELEVATION (ft)	ELEVATION (m)	UTM NORTHING	UTM EASTING
1	Glacier Lake	17	Aug	1994	1325	1350	25	R. Clark/D. Duncan	Mt. McGuire	8945	2726	5004.33	689.84
2	Pothole Lake	17	Aug	1994	930	1005	35	R. Clark/D. Duncan	Mt. McGuire	8640	2633	5001.09	690.59
3	Big Clear Lake	17	Aug	1994	1025	1050	25	R. Clark/D. Duncan	Mt. McGuire	8562	2610	5003.97	690.85
4	Gooseneck Lake	17	Aug	1994	1240	1315	35	R. Clark/D. Duncan	Mt. McGuire	8707	2654	5004.02	690.05
5	Crater Lake	17	Aug	1994	1140	1210	30	R. Clark/D. Duncan	Mt. McGuire	8707	2654	5003.72	690.40
6	Mirrow Lake	16	Aug	1994	1450	1520	30	R. Clark/D. Duncan	Mt. McGuire	8168	2490	5002.07	688.60
7	Gentian Lake	15	Aug	1994	1610	1745	95	R. Clark/D. Duncan	Mt. McGuire	8630	2630	5002.76	689.90
8	Birdbill Lake	15	Aug	1994	1755	1800	65	R. Clark/D. Duncan	Mt. McGuire	8630	2630	5002.40	689.70
9	Shoban	16	Aug	1994	NA	NA	NA	R. Clark/D. Duncan	Mt. McGuire	8610	2624	5002.60	688.60
10	Sheepeater Lake	16	Aug	1994	1055	1135	40	R. Clark/D. Duncan	Mt. McGuire	8653	2637	5002.07	688.60
11	Wilson Lake	15	Aug	1994	1205	1225	20	R. Clark/D. Duncan	Mt. McGuire	8900	2713	5001.51	689.67
12	Harbor Lake	15	Aug	1994	1325	1400	35	R. Clark/D. Duncan	Mt. McGuire	8922	2719	5001.40	689.60
13	Heart Lake	15	Aug	1994	855	930	35	R. Clark/D. Duncan	Mt. McGuire	8623	2628	5000.56	689.30
14	Welcome Lake	14	Aug	1994	1535	1650	75	R. Clark/D. Duncan	Mt. McGuire	8332	2540	4999.97	689.63
15	Skyhigh Lake	29	July	1994	1200	1330	90	D. Duncan	Hoodoo Meadows	8632	2631	49998.80	688.50
16	Turquoise Lake	30	July	1994	900	1020	80	D. Duncan	Hoodoo Meadows	8612	2625	4997.90	687.90
17	Echo Lake	30	July	1994	1035	1135	60	D. Duncan	Hoodoo Meadows	8500	2591	4997.50	688.30
18	Reflection Lake	29	July	1994	1610	1735	85	D. Duncan	Hoodoo Meadows	8109	2472	4997.50	688.60
19	Twin Cove Lake	30	July	1994	1615	1735	80	D. Duncan	Hoodoo Meadows	8300	2530	4996.80	688.50
20	Fawn Lake	31	July	1994	1145	1210	25	D. Duncan	Hoodoo Meadows	7700	2347	4996.40	689.00
21	Doe Lake	31	July	1994	1055	1145	50	D. Duncan	Hoodoo Meadows	7700	2347	4996.40	689.00
22	Buck Lake	31	July	1994	945	1050	65	D. Duncan	Hoodoo Meadows	7700	2347	4996.40	689.10
23	Tip Top Lake	31	July	1994	1600	1630	30	D. Duncan	Hoodoo Meadows	8361	2548	4995.30	688.00
24	Unnamed (NW Ramshorn)	31	July	1994	1700	1730	30	D. Duncan	Hoodoo Meadows	8500	2591	4995.35	687.65
25	Ramshorn Lake	1	Aug	1994	855	1020	85	D. Duncan	Hoodoo Meadows	8114	2473	4994.80	688.00
26	Paragon Lake	31	July	1994	1415	1535	80	D. Duncan	Hoodoo Meadows	8554	2607	4994.70	687.50
27	Alpine Lake	1	Aug	1994	1730	1810	40	D. Duncan	Hoodoo Meadows	8400	2560	4994.15	687.70
28	Unnamed (SE Alpine)	1	Aug	1994	1640	1710	30	D. Duncan	Hoodoo Meadows	8093	2467	4993.80	688.00

Appendix C. 1994 Bighorn Crags amphibian, fish, and lake survey data.

				FISH SURVEY DATA:			AMPHIBIAN SURVEY DATA:						
SITE #	LOCALITY	SURFACE	PERIMETER	FISH	FISH	YEAR LAST	RAPR	RAPR	RAPR	AMMA	AMMA	AMMA	ASTR
		AREA (ha)	(km)	OBSERVED	SPECIES	STOCKED	ADULT	JUVENILE	TADPOLE	ADULT	JUVENILE	LARVAE	TADPOLE
1	Glacier Lake	2.87	0.91	Yes	Cutthroat	1992	0	0	0	0	0	0	0
2	Pothole Lake	0.62	0.30	Yes	Cutthroat	1992	7	0	2	0	0	0	0
3	Big Clear Lake	8.19	1.31	Yes	Cutthroat	1992	1	0	0	0	0	0	0
4	Gooseneck Lake	1.84	0.80	Yes	Cutthroat	1992	0	0	0	0	0	0	0
5	Crater Lake	3.25	0.73	Yes	Cutthroat	1992	0	0	0	0	0	0	0
6	Mirrow Lake	1.23	0.50	Yes	Cutthroat	1992	9	0	0	0	0	0	0
7	Gentian Lake	2.59	1.05	Yes	Cutthroat	1992	15	0	10	0	0	1	0
8	Birdbill Lake	1.31	0.59	Yes	Cutthroat	1992	1	0	0	0	0	0	0
9	Shoban	1.92	0.82	Yes	Cutthroat	1992	0	1	0	0	0	0	0
10	Sheepeater Lake	2.76	0.89	Yes	Cutthroat	1992	0	0	0	0	0	0	0
11	Wilson Lake	2.29	0.61	Yes	Cutthroat	1992	0	0	0	0	0	0	0
12	Harbor Lake	7.79	1.48	Yes	Cutthroat	1992	0	0	0	0	0	0	0
13	Heart Lake	2.31	0.69	Yes	Cutthroat	1992	0	0	0	0	0	0	0
14	Welcome Lake	1.69	0.93	Yes	Cutthroat	1992	9	0	13	0	0	0	0
15	Skyhigh Lake	3.98	0.76	Yes	Cutthroat	1992	19	0	0	0	0	0	0
16	Turquoise Lake	2.96	0.91	Yes	Cutthroat	1992	0	0	0	0	0	0	0
17	Echo Lake	2.20	0.74	Yes	Cutthroat	1992	0	0	0	0	0	0	0
18	Reflection Lake	3.72	0.89	Yes	Cutthroat	1992	10	0	0	0	0	0	0
19	Twin Cove Lake	4.34	0.91	Yes	Cutthroat	1992	4	0	0	0	0	0	0
20	Fawn Lake	0.40	0.25	No	NA	Unstocked	8	0	500	0	0	0	0
21	Doe Lake	1.26	0.47	Yes	Cutthroat	1992	1	0	0	0	0	0	0
22	Buck Lake	1.76	0.50	Yes	Cutthroat	1992	0	0	0	0	0	0	0
23	Tip Top Lake	1.20	0.42	No	NA	Unstocked	600	0	10	1	0	5	0
24	Unnamed (NW Ramshorn)	0.65	0.31	No	NA	Unstocked	13	0	1	2	0	1	0
25	Ramshorn Lake	3.93	0.94	Yes	Cutthroat	1992	25	0	0	0	0	0	0
26	Paragon Lake	3.72	0.92	Yes	Cutthroat	1992	77	0	0	0	0	0	0
27	Alpine Lake	1.04	0.44	No	NA	Unstocked	18	0	40	0	0	5	0
28	Unnamed (SE Alpine)	0.72	0.35	No	NA	Unstocked	43	0	100	0	0	30	0

Appe C. 1994 Bighorn Crags amphibian, fish, d lake survey data.

			WEATHER DATA:			PHYSICAL DATA:								
SITE #	LOCALITY	SURVEY		% CLOUD		AIR	WATER	WATER						
		METHOD	WEATHER	COVER	WIND	TEMP (C)	TEMP (C)	COLOR	TURBIDITY	pH	TDS	ORIGIN	DRAINAGE	DESCRIPTION
1	Glacier Lake	visual/dip net	Clear	5	light	18.6	17.0	clear	clear	7.5	10	natural	permanent	perm. lake
2	Pothole Lake	visual/dip net	Clear	10	calm	18.0	16.4	clear	clear	7.6	10	natural	permanent	perm. lake
3	Big Clear Lake	visual/dip net	Clear	25	light	16.5	17.9	clear	clear	7.6	10	natural	permanent	perm. lake
4	Gooseneck Lake	visual/dip net	Clear	20	light	17.8	18.2	clear	clear	7.4	10	natural	permanent	perm. lake
5	Crater Lake	visual/dip net	Clear	10	calm	16.6	16.9	clear	clear	7.6	0	natural	permanent	perm. lake
6	Mirrow Lake	visual/dip net	Clear	0	calm	18.8	20.5	clear	clear	7.7	10	natural	permanent	perm. lake
7	Gentian Lake	visual/dip net	Clear	5	light	21.0	22.6	clear	clear	7.4	10	natural	permanent	perm. lake
8	Birdbill Lake	visual/dip net	Clear	10	light	19.1	19.0	clear	clear	7.7	10	natural	permanent	perm. lake
9	Shoban	visual/dip net	Clear	0	calm	NA	NA	clear	clear	NA	NA	natural	permanent	perm. lake
10	Sheepeater Lake	visual/dip net	Clear	0	calm	15.0	15.9	clear	clear	7,8	10	natural	permanent	perm. lake
11	Wilson Lake	visual/dip net	Clear	0	calm	18.4	18.0	clear	clear	7.7	10	natural	permanent	perm. lake
12	Harbor Lake	visual/dip net	Clear	0	calm	18.4	18.8	clear	clear	7.6	10	natural	permanent	perm. lake
13	Heart Lake	visual/dip net	Clear	0	calm	16.0	16.8	clear	clear	7.8	20	natural	permanent	perm. lake
14	Welcome Lake	visual/dip net	Over	85	calm	20.3	18.0	clear	clear	7.7	50	natural	permanent	perm. lake
15	Skyhigh Lake	visual/dip net	Clear	5	calm	19.8	17.7	clear	clear	7.2	NA	natural	permanent	perm. lake
16	Turquoise Lake	visual/dip net	Rain	100	calm	13.6	17.0	clear	clear	5.8	NA	natural	permanent	perm. lake
17	Echo Lake	visual/dip net	Rain	100	calm	14.2	16.8	clear	clear	7.3	NA	natural	permanent	perm. lake
18	Reflection Lake	visual/dip net	Rain	100	calm	19.0	19.0	clear	clear	6.3	NA	natural	permanent	perm. lake
19	Twin Cove Lake	visual/dip net	Clear	15	light	14.0	17.8	clear	clear	7.7	NA	natural	permanent	perm. lake
20	Fawn Lake	visual/dip net	Clear	10	calm	20.0	20.2	clear	clear	7.4	NA	natural	permanent	perm. pond
21	Doe Lake	visual/dip net	Clear	5	calm	20.2	20.8	clear	clear	8.0	NA	natural	permanent	perm. lake
22	Buck Lake	visual/dip net	Clear	5	calm	22.2	19.4	clear	clear	8.0	NA	natural	permanent	perm. lake
23	Tip Top Lake	visual/dip net	Rain	100	calm	14.4	19.8	clear	clear	7.4	NA	natural	permanent	perm. pond
24	Unnamed (NW Ramshorn)	visual/dip net	Over/Rain	100	calm	13.8	19.8	clear	clear	7.7	NA	natural	permanent	perm. lake
25	Ramshorn Lake	visual/dip net	Clear	0	calm	22.4	18.0	clear	clear	6.5	NA	natural	permanent	perm. lake
26	Paragon Lake	visual/dip net	Over/Rain	100	Light	20.0	20.2	clear	clear	7.0	NA	natural	permanent	perm. lake
27	Alpine Lake	visual/dip net	Over	100	calm	15.0	20.6	clear	clear	7.6	NA	natural	permanent	perm. lake
28	Unnamed (SE Alpine)	visual/dip net	Over	100	calm	20.2	20.2	clear	clear	7.3	NA	natural	permanent	perm. lake

Appendix C. 1994 Bighorn Crags amphibian, fish, and lake survey data.

SITE #	LOCALITY	NWI SYSTEM	NWI SUBSYSTEM	NWI CLASS	NWI SUBCLASS	LAKE LENGTH (m)	LAKE WIDTH (m)	PRIMARY SUBSTRATE	NORTH SHORE CHARACTER	DISTANCE TO FOREST (M)
1	Glacier Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Cobble-Gravel	200	150	cobble	NA	0
2	Pothole Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Mud	50	50	silt/mud	shallows	0
3	Big Clear Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	400	200	si/m/sa/g	NA	3
4	Gooseneck Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	200	100	sand/gravel	NA	0
5	Crater Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Cobble-Gravel	250	150	cobble	NA	0
6	Mirrow Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Mud	150	50	silt/mud	NA	0
7	Gentian Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	400	50	sand/gravel	shallows/em	5
8	Birdbill Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	200	50	sand/gravel	shallows	5
9	Shoban	Lacustrine	Limnetic	Unconsolidated Bottom	Cobble-Gravel	200	100	san/grav/cob	shallows	5
10	Sheepeater Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Cobble-Gravel	200	150	san/grav/cob	shallows	5
11	Wilson Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	175	100	sand/gravel	shallows	3
12	Harbor Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	300	300	sand/gravel	shallows	5
13	Heart Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	220	75	sand/gravel	NA	4
14	Welcome Lake	Lacustrine	Littoral	Unconsolidated Bottom	Mud	300	50	silt/mud	shallows	2
15	Skyhigh Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	200	200	sand/gravel	shallows	0
16	Turquoise Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Cobble-Gravel	250	100	cobble	NA	25
17	Echo Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Mud	300	50	silt/mud	shallows	0
18	Reflection Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	250	150	sand/gravel	NA	0
19	Twin Cove Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Mud	250	150	silt/mud	NA	0
20	Fawn Lake	Palustrine	NA	Unconsolidated Bottom	Mud	30	25	silt/mud	shallows/em	0
21	Doe Lake	Lacustrine	Littoral	Unconsolidated Bottom	Mud	150	75	silt/mud	shallows/em	0
22	Buck Lake	Lacustrine	Littoral	Unconsolidated Bottom	Mud	150	100	silt/mud	shallow/em	0
23	Tip Top Lake	Palustrine	NA	Unconsolidated Bottom	Mud	100	75	silt/mud	shallows/em	0
24	Unnamed (NW Ramshorn)	Lacustrine	Limnetic	Unconsolidated Bottom	Cobble-Gravel	70	50	cobble	NA	0
25	Ramshorn Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Sand	300	150	sand/gravel	NA	0
26	Paragon Lake	Lacustrine	Limnetic	Unconsolidated Bottom	Mud	250	100	silt/mud	shallows	0
27	Alpine Lake	Palustrine	LIttoral	Unconsolidated Bottom	Mud	100	75	silt/mud	shallows/em	0
28	Unnamed (SE Alpine)	Lacustrine	Limnetic	Rocky Bottom	Rubble	75	75	co/bo/be	NA	50